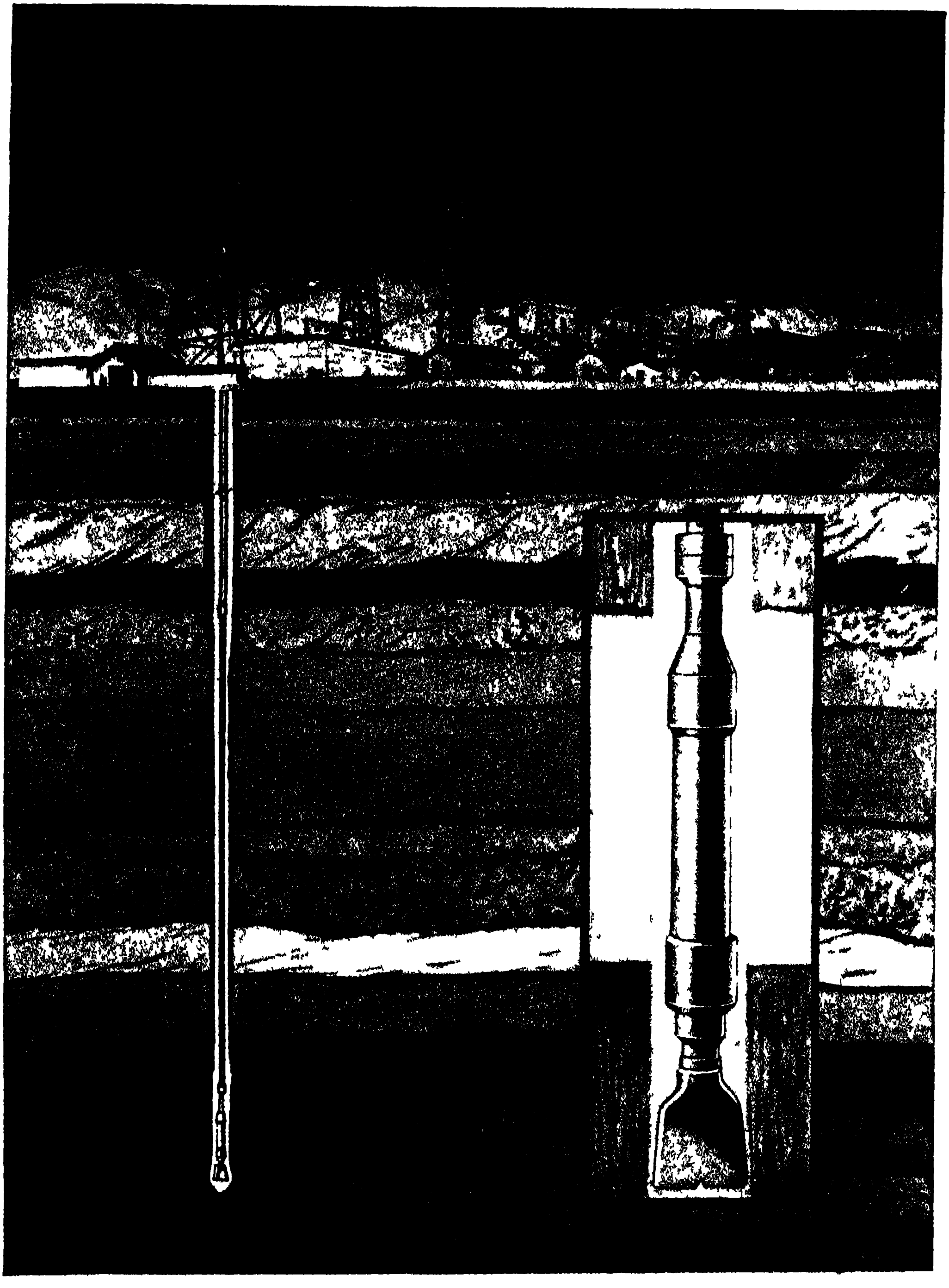
NEWNES'
PICTORIAL KNOWLEDGE

VOLUME SIX



Specially painted for this work

BORING FOR OIL BY TURBINE

This picture illustrates one of the modern methods of drilling oil wells. Liquid mud is pumped at high pressure through a non-revolving pipe to a turbo-drill (shown on an enlarged scale on the right) at the bottom of the well. The casing of the turbo, which is fixed to the pipe and thus cannot revolve, contains a small turbine. As the mud flows through the turbine it makes it The turbine's shaft is connected with the drill through the casing, so the drill also is rotated. Having done its work, the mud escapes at the bottom of the casing and flows back to the surface outside the pipe.

NEWNES'
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VOLUME 6

General Editors
R. H. POOLE
PETER FINCH, M.A.

Associate Editor
ENID BLYTON

Technical Editor
E. MOLLOY

Art Editor
A. H. J. HUMPHREYS

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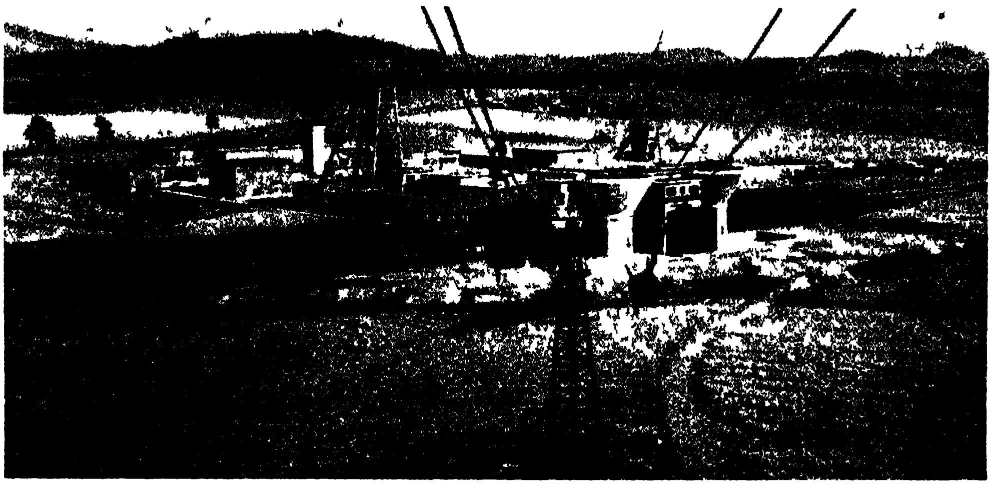

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A MODERN COLLIERY IN SCOTLAND

Coal is of vital importance to British industry and the prosperity of the country largely depends upon the output from our mines In the past few years mechanisation in the collieries has been speeded up and many new types of machinery introduced Even the outward appearance is changing to some extent, as shown in this photograph of the general surface layout of the Comrie Colliery in Fifeshire

THE STORY OF A LUMP OF COAL

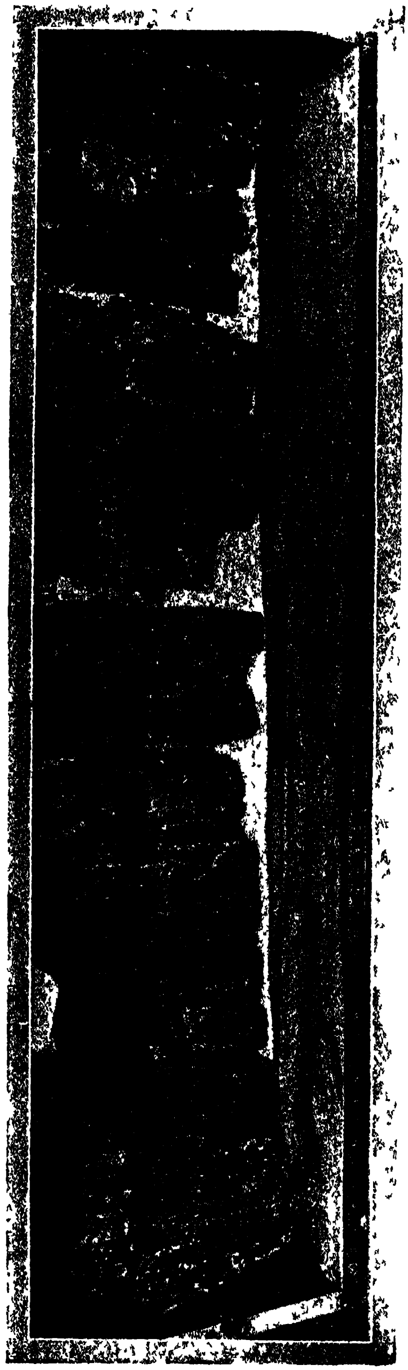
A VERY old proverb says that familiarity breeds contempt One might widen the proverb by using the word "indifference" in place of "contempt" There are many very useful things which we take for granted because we have always been accustomed to seeing and having them

Product of the Sun

Among these last is coal Its great value to us has been fully recognised in the past few years, yet we smash it up roughly and shovel it thoughtlessly, and often wastefully, into furnaces or on to the fire, and while enjoying the heat which it gives us, grumble at it for the dust, dirt, soot and smoke which it makes

Coal deserves our greatest respect, if only on account of its age That lump of coal now burning on the fire came into existence during the passage of perhaps many millions of years, and was what it is now untold centuries before man first began to people the earth It is the product of ages of sunshine, moist atmosphere and rank growth, followed by burial and an enormously long period of steadily increasing pressure, resulting in the formation of a black rock—for coal must be regarded as a rock—which differs from other rocks in that it burns readily.

Now, suppose that you took a piece of wood, say, a cricket stump, and the lump of coal, and handed them over to a chemist to be analysed, that is, broken up into their elements The report that he would send you would show that both are made up of the



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IN A SEAM OF COAL

A single seam or layer of coal may contain many grades, hard, soft, steam, and so on. Here a section of a seam has been cut and reassembled in a wooden box.

same main things—carbon, nitrogen, hydrogen and oxygen—though the coal would contain a much higher proportion of carbon than the wood. This similarity is not to be wondered at, since coal is nothing more than woody matter that has had a great part of the gases that once were in it squeezed out by a pressure which has altered its structure. It has also been changed by heat and fermentation.

Through a Coal Forest

In the times when the trees and other vegetation which formed our coal were growing, Britain did not exist in its present form. It was merely part of a vast swampy expanse covered with a very strange growth. We know what the trees and plants of the period were like from remains that have been found in coal itself, or in the layers of clay above and below the coal-seams.

We may picture vast, gloomy forests of monkey-puzzle trees, gigantic reeds, and plants which resembled our club-mosses, but grew to a height of 60 feet, and had trunks up to 5 feet in thickness. The scene could hardly have been picturesque, as most of the trees had tall, straight trunks, with very few branches at the top, and very few leaves on a branch. They lacked entirely the beauty of our own forest trees.

Among the trees was a luxuriant growth of many kinds of ferns, with large fronds curling like the end of a bishop's crozier; and there may have been some plants bearing flowers, which began to appear at this period of the earth's history. In and out between the trees flitted insects of many kinds, but there were as yet no birds; and over the slime in which this vegetation was rooted crawled worms, snails, and various reptiles. The lagoons spreading here and there contained fish and molluscs. In many ways the coal forest, with its slime, decaying vegetation, and hot, moist atmosphere, must have been somewhat like a modern mangrove forest, and probably as unpleasant a place for men to live in—if there had been any men.

We may imagine many generations of trees and plants growing, and rotting into a carpet of stems, roots and leaves, similar to

the pulpy mass of a peat bog until it has a thickness of many feet. All the time the ground is sinking very, very slowly. Then there begins a quicker subsidence, and water from the sea or rivers begins to flow in, bringing with it sand and fine particles of rocks. These settle and form a layer of dense clay or sandstone over the vegetation. Presently the filling-up reaches a stage at which it becomes possible for vegetation to grow again, and what was once open water returns to forest. This in turn sinks, and is covered up; and the alternate processes of growth and burial may be repeated many times.

The "Coal Measures"

In the end, one gets a series of seams of coal, separated by layers of clay, shale, and sandstone. A "coal measure," as such a series is called, may be compared to streaky bacon. The lean is represented by coal and the fat by the other materials. The coal seams may vary in thickness from a few inches to many feet; and the same seam may contain coal of different qualities, produced, perhaps, from different kinds of vegetation.

Ages pass, and there is a further sinking of the ground. If the settlement is great, the ground may be covered deeply with sea-water. The lime-encrusted remains of myriads of tiny creatures living in this settle to the bottom and in the course of a million years or so produce a thick layer of chalk, which itself may have strata of clay and sand spread over it.

One should notice that the layers found over the coal measures always come in the same order, though they are not all present in every case; and that they are all deposited from water, unless it should so happen that some molten rock has been forced among them from the interior of the earth. It should be mentioned, too, that coal occurs not only in the true coal measures, but among the layers which cover them. For whenever the conditions were right for the growth of coal-jungle, it grew.

We have pictured the ground as always sinking, to get an orderly view of things. But the earth's crust has moved up as well as down, and upward movements have been responsible for many coal-seams by making it possible for vegetation to grow. It was upheaval of the layers that brought much of the world's coal within

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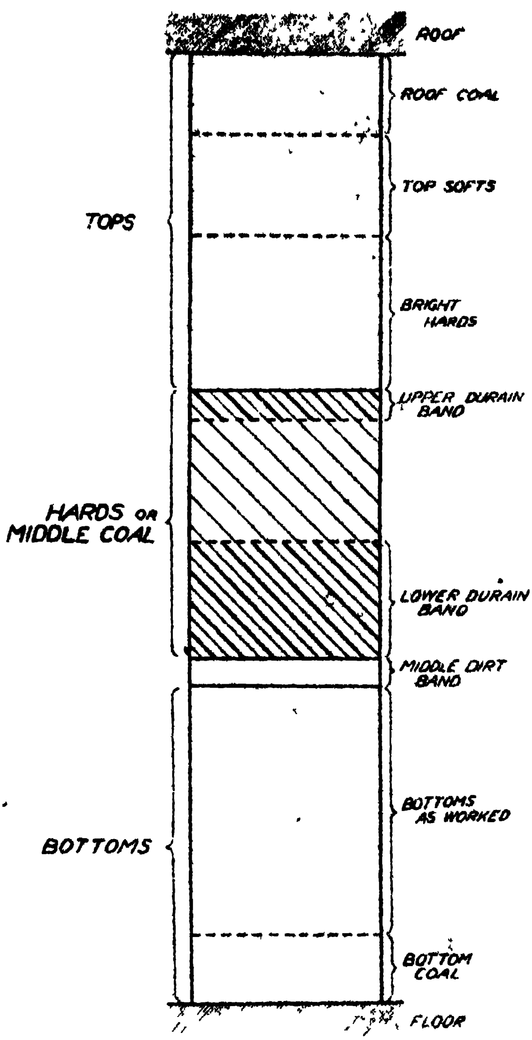
A LIGHTER FORMATION

The seam of coal here depicted is scarcely half the thickness of the layer shown on the previous page. Coal seams vary considerably

our reach. In many cases the coal-seams have been pushed up above sea-level, at least along their edges, and so can be mined by tunnels driven into them. In some places seams of coal are visible in sea-cliffs and river banks ; in others, in mountain sides. Most of the British coal deposits, however, lie along the bottom of great shallow basins of rock, filled in with more recent formations ; and, fortunately for us, they are very level and unbroken, so that, once reached, they are easy to mine.

INTRODUCTION



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ALL FOUND IN ONE SEAM

To many of us all coal appears alike, but the expert divides it up into different classes and qualities, largely according to its non-carbon contents, as is here illustrated. Coal in the seam varies according to the materials out of which the "measures" were formed in the earliest ages of the earth.

Varieties of Coal

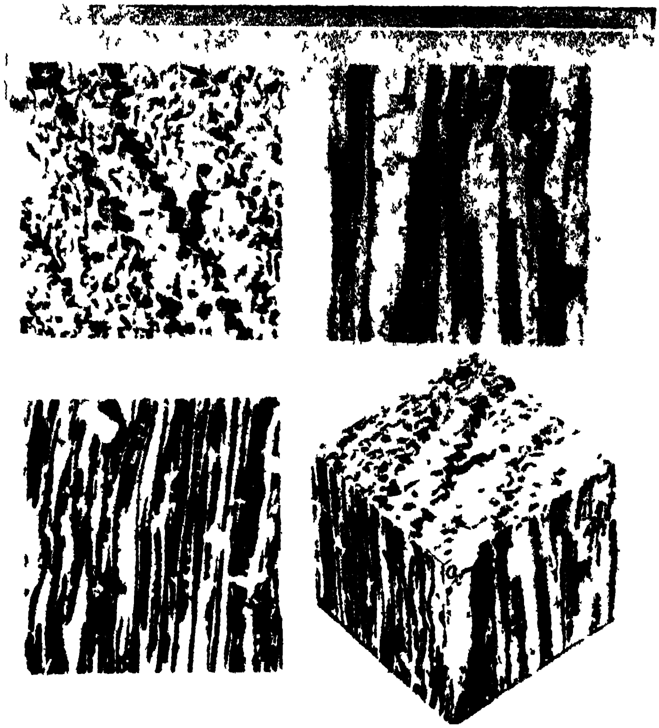
There are different kinds of coal, and though they all burn, they behave in different ways.

What we may call the youngest kind of coal is named *lignite*, from the Latin word *lignum*, a log, because the shapes of tree-trunks are plainly to be seen in it. It is also called "brown coal," being in some cases of much the same colour as peat, though it is sometimes black. We may regard it as imperfectly formed coal, containing a great deal of water, and much less carbon than true coal. Very little of it is found in Britain, but it is plentiful in Germany, North America and Australia. It burns smokily, and is unsuitable for household use, though large quantities are consumed in power stations supplying electricity to big cities.

The next and largest class of coal is *bituminous* coal. This has been squeezed and heated more than lignite, and has got rid of much of its hydrogen. But a good deal of that gas still remains in it, and

it burns with a bright flame, and some smoke. The harder and less gaseous varieties are used a great deal in steam boilers, while the softer kinds, which send out spurts of gas when burning and tend to cake together, are in great demand as household coals and for making gas.

Then we come to the purest coal of all, *anthracite*, mined chiefly in South Wales and Pennsylvania. Owing to its great hardness it is also called "stone coal." It is practically pure carbon, and so burns slowly and without flame or smoke, like charcoal or coke, and it leaves very little ash. It is used chiefly in enclosed stoves for heating houses or water, or for cooking.



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COAL OF VARYING STRUCTURE

From these micro photographs we can see that coal is built up of many layers or structures. Polished coal surfaces show us a grain not unlike that of wood. Prints of this nature may be placed together to demonstrate the formation of a cube of coal as shown in the lower right hand corner.

For "Lead Pencils"

In graphite, or plumbago, used in making "lead" pencils, we may have coal in a still purer state, every substance other than carbon having been driven out of it almost entirely by extreme pressure lasting for many more years; and in the diamond we may have the final stage, in which intense heat has played a part, producing absolutely pure carbon in a crystallised form. So you see that there is some reason in calling coal "black diamonds," apart from the question of its value to us.

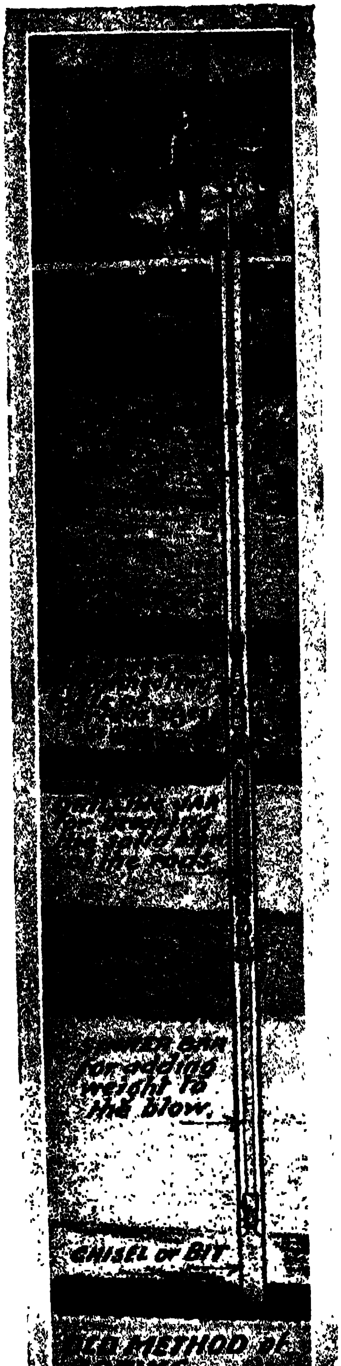
Why do some coals burn with little ash, while others leave a great deal?

The chief reason, no doubt, is that, while the coal vegetation was being covered up, it got more or less intermingled with sand and clay brought in by water. In one place the water might have been strained by vegetation or been purified by depositing any solid matter in it before it reached the forests; and in another it may have come in with more of a rush, and dumped tiny fragments of rock among the coal of the future.

Or, again, some trees and plants may have contained more unburnable matter than others.

The Early Use of Coal

The Romans first made use of coal in these islands. We know that they burned it, because coal ashes have been found among the ruins of old Roman military stations in Durham, Northumberland and Lancashire. After the Romans left Britain, the mineral seems not to have been employed for many

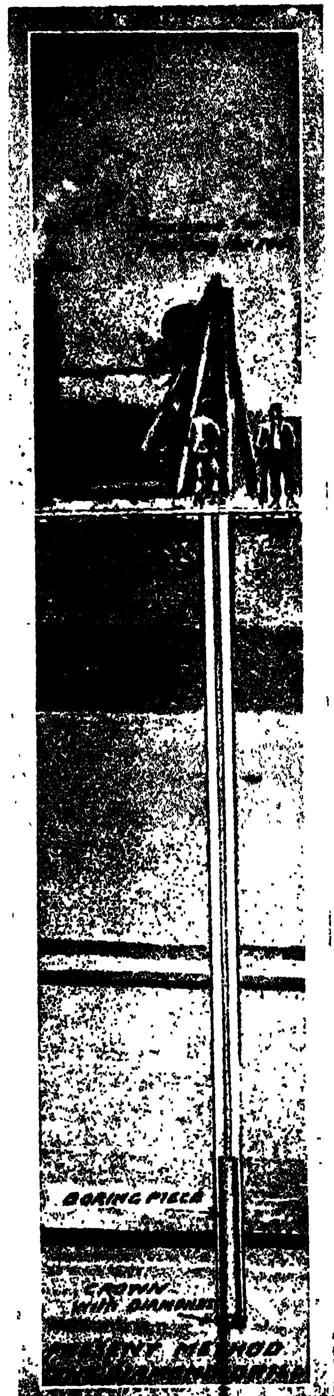


In days gone by the earth was bored to make tests for coal by means of a string of tools, as illustrated. It was not a satisfactory method.

centuries. No mention is made of it in Domesday Book (1086), which gives a very complete record of all minerals known at the time.

By the thirteenth century people were beginning to collect lumps of coal found on the sea-shore along the north-eastern coast of England. It was called "sea-coal," to distinguish it from charcoal, the common fuel, and this name stuck to it for four centuries, long after inland coal-mines were working. Then the monks of Tynemouth began to mine it in a small way, sinking shallow pits into the coal where it came near the surface, and their example was copied in Derbyshire, Yorkshire, South Wales, Shropshire and Staffordshire.

So long ago as 1253 a street in London was called Secole Lane, and this shows that already coal was being shipped to the capital. But until the fourteenth century none but poor people used this kind of fuel, and it was only when buildings were provided with chimneys to carry away the smoke that it found its way into the houses of the great. Even then there was considerable prejudice against it as being injurious to health, and people generally had to be more or less driven to its use by the



Our mining engineers now depend upon the diamond drill, depicted above. By this means a core can be brought to the surface

dwindling supply of charcoal.

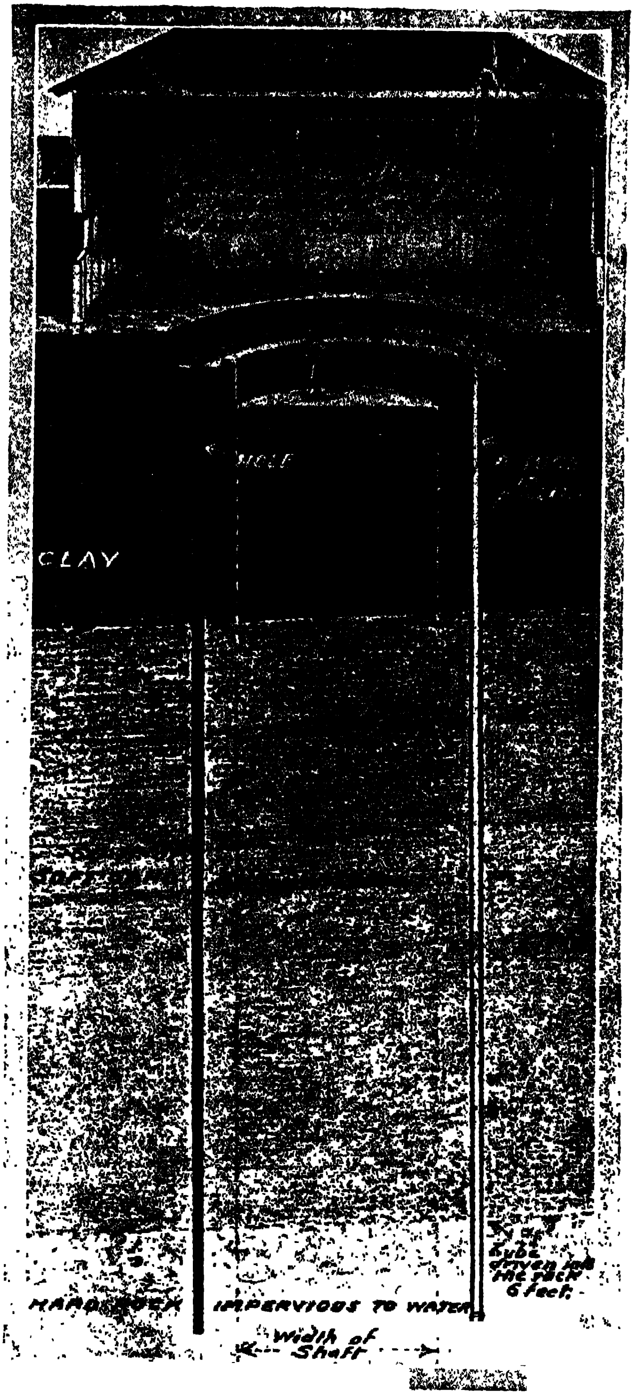
Queen Elizabeth, though she levied taxes on mined coal, would have nothing to do with it ; but her successor, James I., had been accustomed to burning coal at his seat in Fife, and introduced it to the palace of Westminster. As soon as the royal favour shone upon it, coal became fashionable, and we read that in James's reign "pitt-cole is become the general fewell of this Britaine Island, used in the houses of the nobilitie, cleargy and gentrie in Londone and in all other cities and shyres of the Kingdome."

It is an interesting fact that St. Paul's Cathedral and many parish churches destroyed in the Great Fire of 1666 were rebuilt largely with money got by taxing coals imported into London.

What established coal-mining as a great national industry was the adoption of coal, about the middle of the eighteenth century, for iron smelting, and the application of the steam-engine to keeping mines clear of water.

Boring and Shaft-sinking

British coal lies far below the surface, and must be raised through shafts—great wells sunk into the ground till they reach the seams. The shafts allow men to enter and leave the workings, give entrance to all articles, such as timber, rails and machinery, needed for getting coal ; provide a way out for the mined coal, and for water pumped to the



L.E.A.

SINKING THROUGH SOFT SAND AND WATER

This sectional drawing shows how a coal pit was sunk through soft sand and water. Tubes were driven 6 feet into hard rock below the sand. Through these tubes a freezing mixture was circulated.

surface; and are the channels through which the mine is ventilated.

The sinking of a shaft may cost hundreds of thousands of pounds. So, before one is sunk the ground is explored thoroughly to find out whether the coal seams will justify the expense, how deep down they are, and where the shaft may best be placed. Test-holes are put down in selected places. An engine is erected over the spot chosen for a hole, to work a drilling apparatus. The tools used are in some cases heavy chisels, fixed to the ends of iron rods, lifted and dropped by the engine, and given part of a turn between blows.

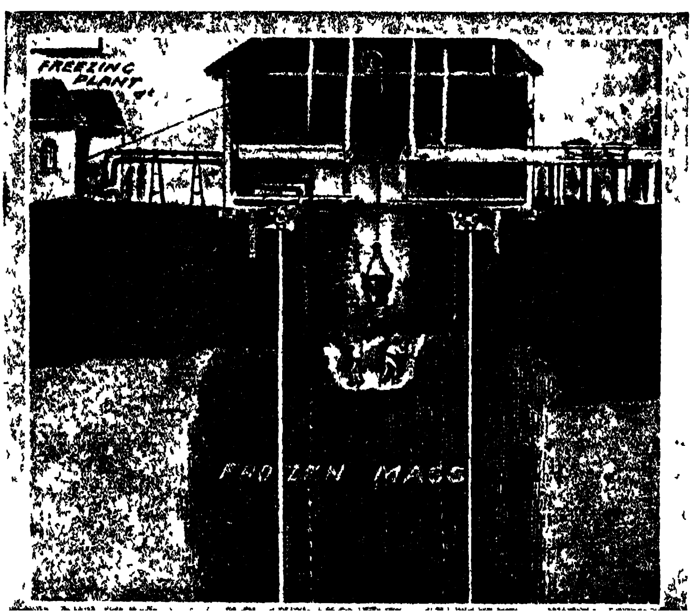
But if complete samples, or "cores," of the strata passed through are wanted, the rotary drill is used. This is a short hollow cylinder with its bottom edge studded with diamonds, or having removable hard sharp spikes projecting from it. Or it may be grooved at the bottom, so that hard steel shot may be fed between it and the material it is boring, to wear the latter away.

The drill is on the end of a string of hollow rods, through which water is pumped to wash up the fine matter worn away by the drill as it turns round and round. When the drill has cut out a core of its own length, grit is poured down the tube to wedge the core, and the drill is lifted to the surface, bringing the core with it. The core is removed, examined, and numbered, and the drill lowered again. In this way ground has been explored completely to a depth of 7,000 feet.

If the bore-hole passes through a soft, water-bearing stratum, such as quicksand, it has to be lined with steel tubing, driven down from the surface, until firm ground is again met with.

Lining the Shaft

We will assume that it has been decided to sink a shaft. In Britain, coal-mine shafts are usually circular, as this shape resists great pressure most easily; and square-cornered shafts are used only in firm, dry ground. In any case, the shaft will be lined from top to bottom with masonry, concrete or iron. Where the ground is loose or soft, it is removed with pick and shovel; while rock has to be bored and blasted. Where a masonry lining is used, it is built in sections as the sinking proceeds. At intervals a deep groove is made in the side of the excavation, and in it a wooden ledge, or curb, is fixed. This curb acts as the



L.E.A.

DIGGING THE SHAFT OF A COAL-MINE

This picture shows a continuation of the engineering feat explained on the previous page. The soft, watery layer of sand has been frozen hard, and men called "sinkers" are now engaged in excavating for the shaft, which at the soft section will be lined with metal plates wedged in position with wood

foundation for masonry, which is built up till it reaches the curb above.

Should a concrete lining be preferred, a steel lining is fixed round the shaft, and the space between it and the ground is filled in with concrete. When the concrete has hardened, the lining is removed, to be used again lower down.

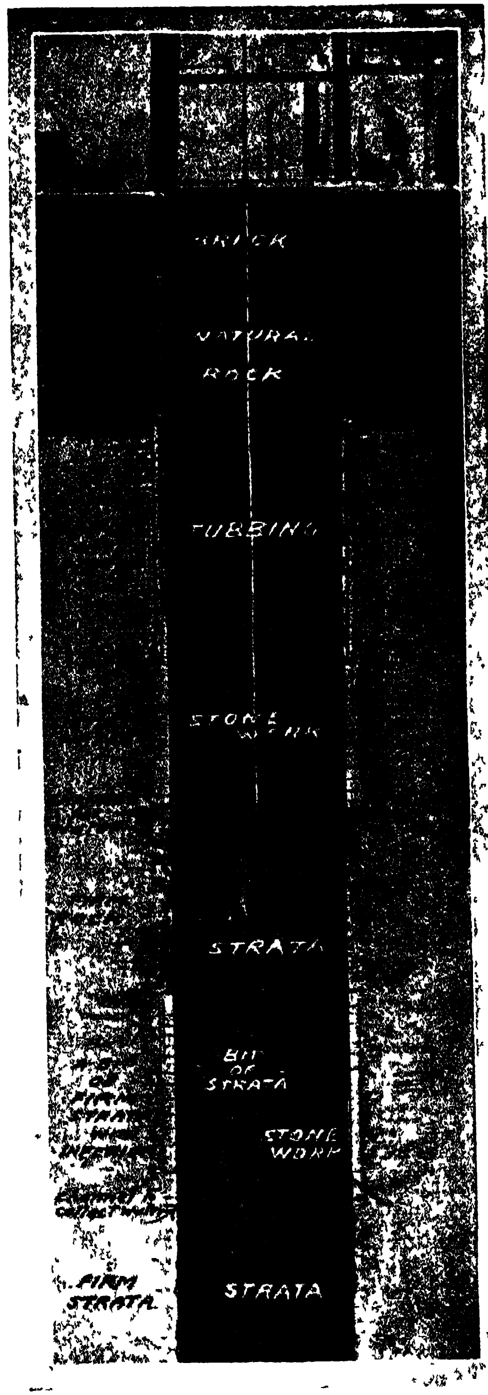
Fighting Water

The shaft-sinker's great enemy is water. If it is known that the shaft will have to pass through water-bearing rock or quicksand, special measures are taken to keep the water at bay while the shaft is being sunk through the watery ground and lined.

When a quicksand has to be pierced, bore holes are sunk through it in a ring, so as to enclose a cylinder of ground a few feet wider across than the shaft will be. Each hole is lined with a steel tube closed at the bottom, and has a smaller tube open at the bottom inside it. Brine chilled far below the freezing-point of water is pumped down through the smaller tube and rises between it and the larger tube. This circulation of brine is kept up for months, until the ground all round the tubes is frozen solid. Then the miners get to work and dig out the frozen sand, and line the shaft with brickwork or iron rings like those used for the lining of a " tube " railway.

The same method may be used for dealing with rock with fissures in it which act as water-channels. But engineers also employ a quite different process, called cementation. In this case open-ended tubes are sunk into the rock, and liquid cement is squirted in under enormous pressure until all the cracks in the rock near the path of the shaft have been filled in, and the rock becomes solid and water-tight. Sinking of the shaft can then proceed as if through dry ground.

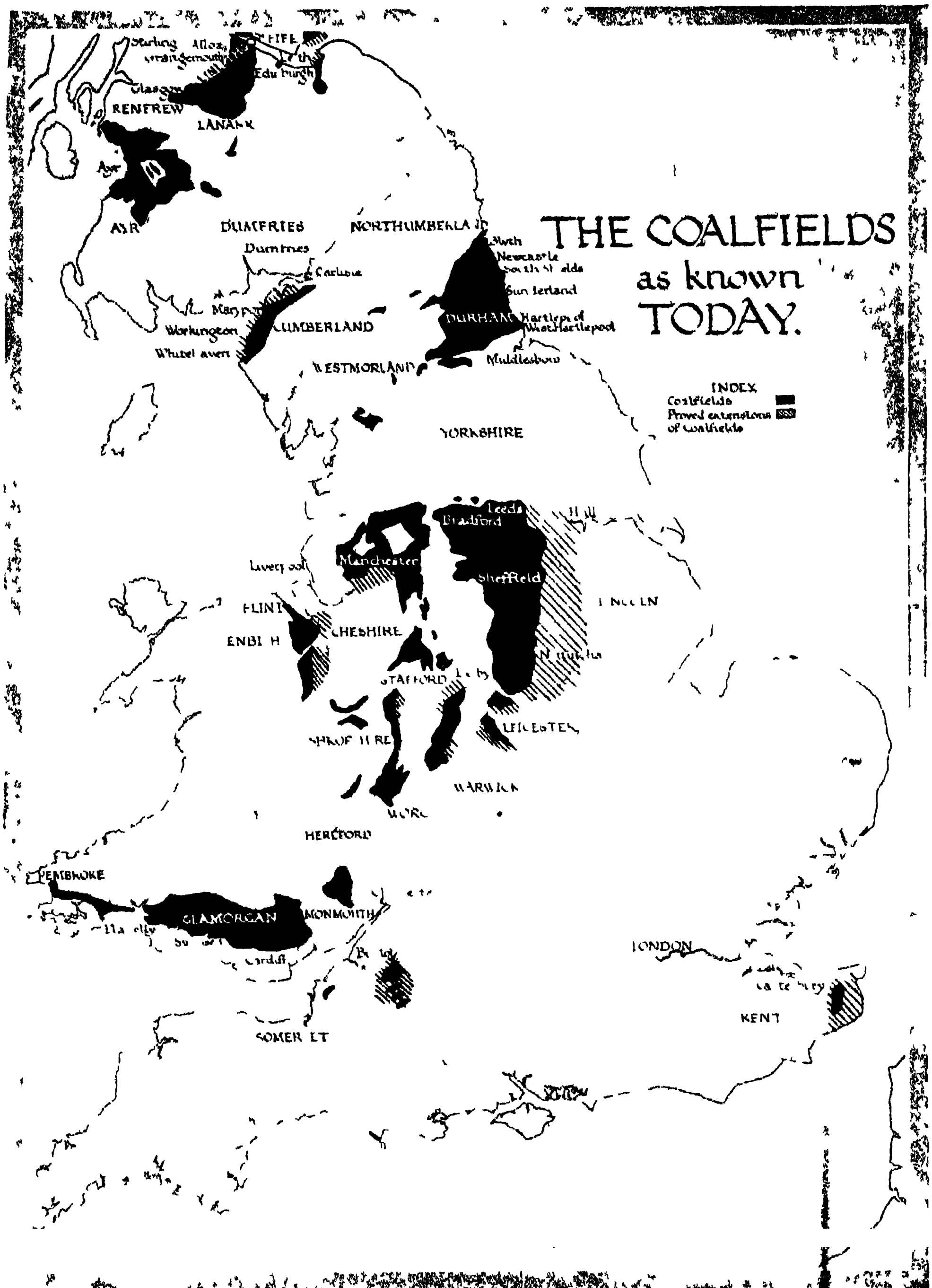
At the bottom of a shaft is a large chamber, lined with strong arches of masonry to carry the weight of the



LINING A MINE SHAFT

The shafts or wells of coal-mines are lined with different materials, according to the strata. In parts the natural rock suffices as a wall, and brickwork serves in places.

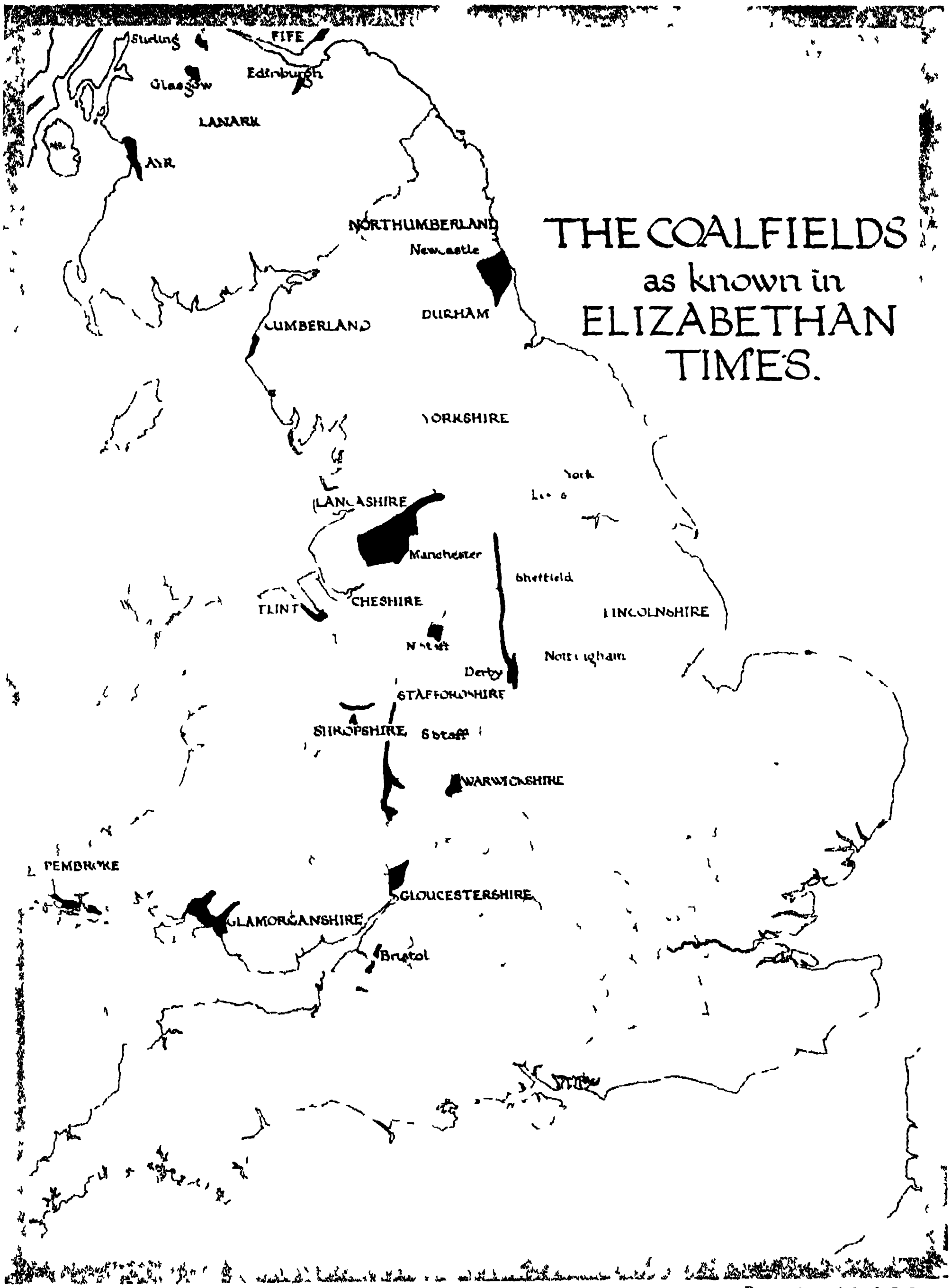
THE PRESENT SOURCES OF OUR COAL



By courtesy of the B B C

This map of part of Great Britain shows in black our coal-fields as they are to-day. Almost all our coal lies far below the surface and must be raised through shafts, which are like great wells sunk in the ground. People live together most thickly in those parts of the country where coal measures are found because the "black diamonds" feed busy factories. The development of the Kentish coal-field is of recent date.

NEARLY FOUR HUNDRED YEARS AGO



By courtesy of the B B C

The first people to burn coal in this country were the Roman invaders, but not for centuries after their departure was the commodity used again. Folk then began to pick up lumps on the seashore near the mouth of the Tyne, calling the fuel "sea-coal" to distinguish it from charcoal, which was normally burned. In the days of Good Queen Bess a tax was levied on mined coal. The above map shows that many coal-fields were known even then.

shaft It extends below the level of the seams, so that water may drain into it from the workings and be pumped up, and it is provided with platforms at which the coal tubs are put on to or drawn off the lifting cages

Ventilation of Mines

Every coal-mine must have at least two shafts equipped with winding gear, so that the miners may not be trapped if one should be blocked Two shafts are needed also to give good ventilation underground

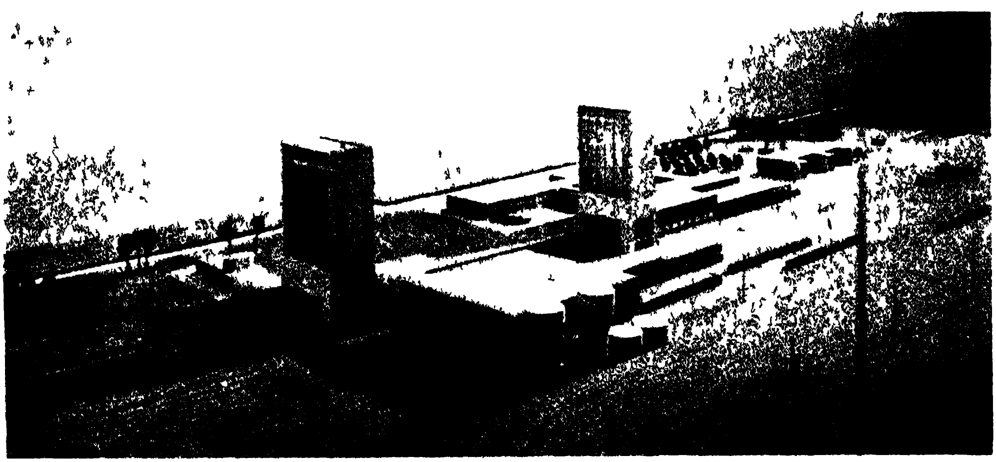
Enormous quantities of air must be circulated through all parts of the workings to supply the miners with plenty of oxygen, as well as to carry away any dangerous gases leaking out of the coal The deeper a mine is, the hotter it becomes, and the greater is the need for an abundance of fresh air to keep the heat within bounds Usually the air-current is produced by a huge fan at the top of one shaft, called the "upcast" shaft The foul air sucked up through this is replaced by fresh air rushing down another shaft, the "downcast," and led through all parts of the mines by light partitions, named brattices, placed in the workings before it reaches the "upcast"

In many mines to-day about 8½ tons of air are circulated every minute of the day This means that 5 or 6 tons of air are often circulated for every ton of coal produced.

Getting water out of a mine is as important as getting air into it Many mines would be flooded if the pumps ceased working a single day In some mines more than 1,000 gallons of water are pumped out every minute of the day, equal in many cases to several times the weight of the coal raised.

Early pumping-engines were set at the top of a shaft and connected by rods with pumps at the bottom Nowadays pumps are usually driven by electric motors placed in a chamber near the foot of the shaft and fed with current through cables running down to them from the surface The pumps themselves may have plungers working in and out, or contain fan-like blades which fling the water from them against the casing with such pressure that it is forced to the surface

Electricity is being more and more used in coal-mines for lighting the workings, hauling coal, and driving mechanical cutters and we have now a number of "all-electric" collieries

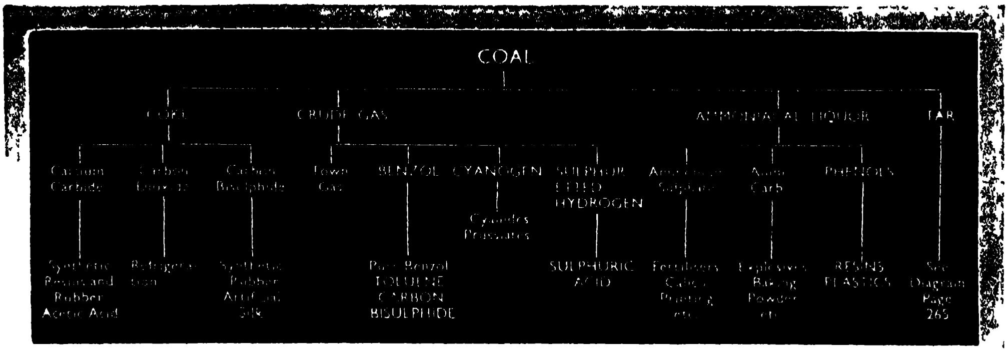


National Coal Board

SCOTLAND'S NEWEST COAL MINE

In every branch of the coal industry new ideas and modern methods are being introduced and the architect is called upon as well as the geologist and engineer This photograph shows the model of the new Rothes Colliery in Fifeshire and gives an excellent idea of what it will look like when completed

WHAT WE OWE TO COAL



Specially drawn or this work.

COAL AND ITS BY-PRODUCTS

We are apt to think of coal mainly as a substance that produces heat by being burned. As a matter of fact, the by-products of this fuel are of almost incalculable importance, as can be seen from this diagram. From the chemist's point of view coal is a complex mixture of valuable chemicals and although the production of gas from coal is not a new story the record of the chemicals now obtained during the process of gas-making is a much newer and more fascinating story.

THE fire having burned rather low, you take a lump of coal from the scuttle in the tongs and throw it on to the fire. Why do you do this? Because you know that the coal will burn and give out heat.

Yet you will be surprised to learn that from coal chemists can derive well over *two thousand* different substances, all of use to us! "Two thousand!" you may say; "surely that is impossible?" It is not impossible, because it is actually being done. Experiments carried out patiently over a long period of years have shown that coal is a real treasure-house. We do not yet know the total of the riches that a lump of coal may conceal under its dull, dirty exterior.

The Elements of Coal

If you were given, say, five little squares of cardboard, each bearing a different number, you could spend a long time arranging them in different orders, without repeating yourself. Every time you made a new arrangement of them they would give you a new value, though the figures themselves would remain individually the same.

Now, in coal we have five main elements; Carbon, hydrogen, nitrogen, oxygen and sulphur. Like the figures, they can be combined together in a great number of different ways; and the substances which result from the different combinations may be far more unlike each other in their qualities than 12345 is unlike 54321 in value.

We get these substances out of coal by breaking it up into its elements, which are made to unite again in various ways.

We can break up coal on a small scale in the following manner: We take a tin canister—a ½-lb. coffee-tin does very well—fill it partly with small coal, replace the lid, and punch a small hole in the bottom. The tin is then placed bottom upwards in a clear fire.

Vapour soon begins to issue from the hole. This is at first mostly steam, from the little water in the coal. Presently the vapour will light if a match be applied to it. A mixture of carbon and hydrogen, called coal-gas, is now coming away. It burns for a long time, but with a smoky flame, because it contains impurities. One of these, tar, blackens the tin round the hole.

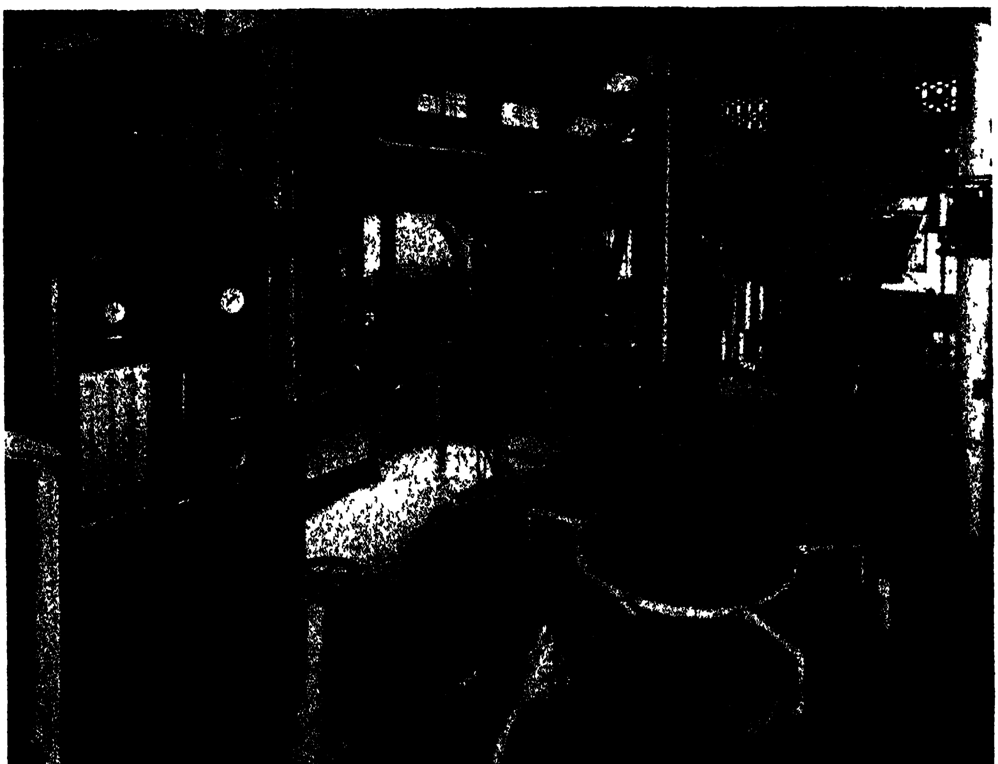
Ammonia gas and sulphur also pass out. When the flame dies down, the coal has parted with everything that can be driven out of it by heat. On the tin being opened, there falls out a mass of coke, which is carbon mixed with certain mineral impurities. When the coke is put into the fire it burns without smoke, and the impurities become ash.

How Coke is Used

You see, then, that we have with our canister broken coal up into several things, two of which, coke and gas, can both be turned to give heat, and the gas to give light as well. Coke is used in stoves and boiler furnaces, and for smelting iron.

In the early days of railways people thought that the smoke from the locomotives would ruin the crops and injure cattle near a track. So for a time the railway companies burned only coke in their engines because it gave out no smoke; and you can still see in places the ruins of the old coke ovens used in those now distant days. But when it was found that, after all, coal smoke from engines did no harm in the country, and that what people took for smoke was mostly steam, coal filled the place of coke. It was less expensive, and a greater weight of it could be carried on the tender, as it took up less room.

Iron-smelters use coke for a different reason, which is that raw coal contains things that would hinder the production of good iron.



Woodall-Duckham Company.

A SCENE INSIDE THE GAS WORKS

Here we have a scene in an up-to-date gas works. In the foreground is the top of a producer with air blast equipment round it, while in the background is the waste heat boiler. The photograph was taken at the Poole and Pitwines works where 236 tons of coal are carbonised each day, making nearly four million cubic feet of gas, besides providing valuable by-products.

Gas Council.

AT THE WORLD'S LARGEST GAS WORKS

Coal is not a simple substance but a complex mixture of valuable chemicals. It is only in comparatively recent times that the full possibilities of these chemicals have been realised, and new discoveries made concerning the by-products obtained from the carbonisation of coal at the gas works. The largest gas works in the world are at Beckton, North Woolwich, seen here.

William Murdoch's Lamp

In the early days of coke-making, no account was taken of the gas. This was allowed to escape into the air. In 1792 a Scottish engineer, William Murdoch, baked coal in iron vessels and collected the gas that came from it in air-tight bags. He would take one of these bags, and fit its neck with a stop-cock and a metal tube having a small hole in the end of it. When he wanted a light to guide him through the darkness to or from his work, he turned on the cock and lit the gas coming from the bag carried under his arm.

Later on, Murdoch lit his house with gas, and presently some works at Birmingham. The idea of conveying gas through pipes for street lighting was soon afterwards taken up. Like most great inventions, gas-lighting had its opponents. It would blow up towns and poison the air, said some. It will destroy our Navy, said others, who argued as follows: "We have used whale-oil for lamps in the past. If we use gas, whale-oil will not be wanted, and the whale fisheries will disappear. As our best sailors are those trained on whalers, our Navy will be ruined when the supply of such sailors ceases."

But arguments similar to these could not stop progress. In 1813 Westminster Bridge was lighted with gas, and people flocked to it to see the new lamps. "How wonderful! How brilliant!" they exclaimed. With the burners then used the brilliancy cannot

have been very great, as compared with our modern street illumination. But it doubtless was an improvement on the murky light from the parish oil-lamps which the gas-jets replaced.

Gas-lighting soon spread all over the country. Every town got its gas-works, and gas pipes invaded one house after another. Explosions might occur, but they were few and far between. So people accepted gas as a good and convenient friend which dispelled darkness and was always at hand when wanted.

Heat Laid on Through Pipes

For many years gas ruled as the king of light in towns. Then a rival—electricity—put forward its claims. The electric lamp was more brilliant, and it did not soil ceilings and decorations. But presently Auer von Welsbach invented the incandescent gas mantle, which in turn beat electric light hollow for a time. Inventors replied with greatly improved electric lamps, and now the victory, so far as lighting is concerned, rests with electricity.

If lighting had been the only use which could be made of coal-gas things might have gone badly with the gas companies. But gas has great advantages as a heat-giving factor ; it can be more easily regulated than any other form of fuel for general use, and its cleanliness, speed and flexibility give it great advantages in such industries as food manufacture, whether in baking bread and cakes, sweet-making, or in cooking a host of other articles of everyday consumption.

In millions of homes all the cooking is now done by gas, which, in effect, is heat laid on through pipes, like water. Hundreds of thousands of rooms and shops are heated by gas fires and gas stoves. And many thousands of factories use furnaces heated by coal-gas for industrial processes. So coal-gas,

Gas Council.

DYEING KNITTED FABRICS AT THE DYE WORKS

It was an Englishman, W. H. Perkin, who first obtained a dye from the substances derived from coal tar, and it was his dye which was first used to print the mauve penny postage stamps in the later years of Queen Victoria's reign. Yet the artificial dye industry was not developed in this country until after the 1914–18 war. To-day we are making 90 per cent. of our own dyes from coal tar,

Gas Council

SHEEP TAKING THEIR ANNUAL DIP

Most of our well known disinfectants come from one or the other of the oils dissolved from the tar produced at the gas works when coal is carbonised to obtain gas. It is from these oils that such preparations as sheep dip are made, and by law all sheep in this country must be dipped once a year. In this photograph sheep are receiving their annual bath.

after being threatened with downfall, is consumed in larger and larger quantities as the years pass by, and more people realise how convenient and clean it is in comparison with the raw coal from which it comes.

The Four Useful Friends

We said a little way back that coal-gas contains impurities. But even these impurities have their uses. Into a gasworks there goes coal. Out of a gasworks there come, besides coke and gas, coal-tar and sulphate of ammonia.

The last of these is the sulphur and nitrogen in the gas, collected and combined together. It is a very valuable fertiliser. Many people scatter it thinly on their lawns to make the grass grow. British farmers use many tons of it each year to help their crops. Some crops must have nitrogen supplied to them in a suitable form, and the sulphate is just the thing for the purpose. A great deal of the food we eat has in it nitrogen derived from coal. Curious, is it not? But it only goes to show that there is more in coal than one may suspect.

A Journey to the Seaside

It is really very difficult to get away from coal. We are off to the seaside for our holidays. How jolly it will be to exchange the smoke-laden air of the town for the fresh sea-breezes!

We hail a taxicab, and are driven to the station over roads made smooth and dustless with the help of coal-tar. The petrol used by the taxicab's engine which hustles us along very possibly contains some spirit — benzole — extracted from coal-tar. The locomotive which rushes us seaward is burning coal. The sleepers which support the rails flying away from under us are soaked with creosote, which is a product of coal-tar. Every one of them contains a large amount of this liquid. We flash past hundreds of telegraph poles, every one of which also has been steeped in the same liquid. And when we reach our destination and again

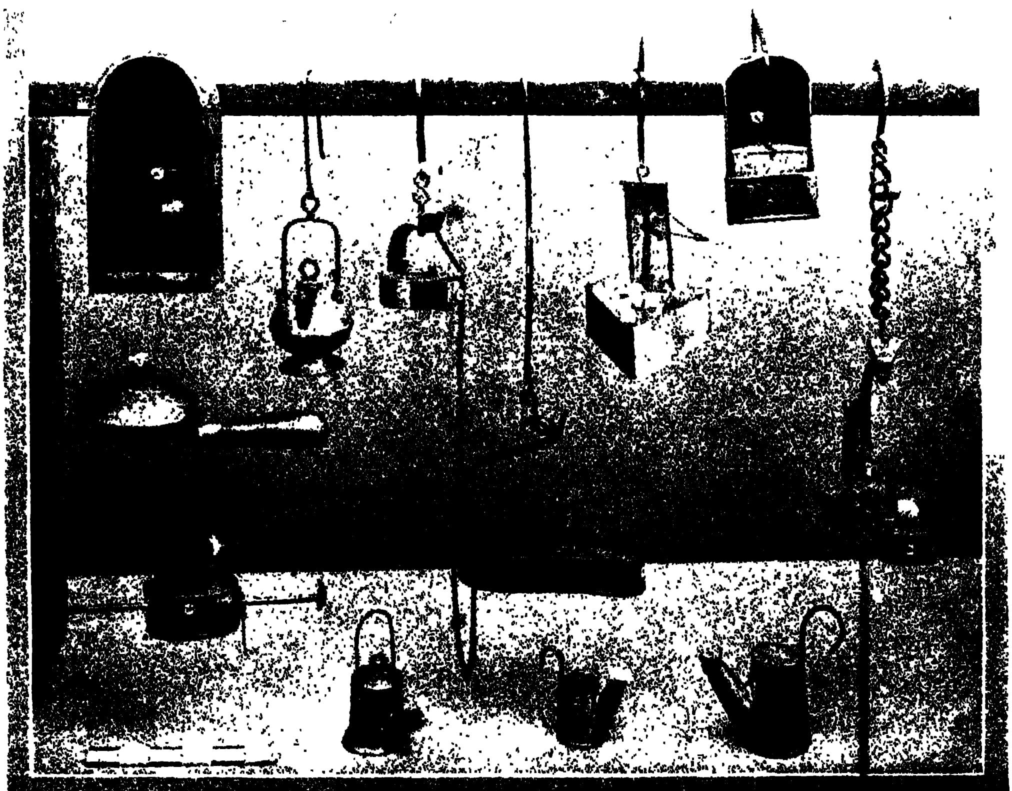
take a cab, as likely as not we shall travel over wood blocks protected from the weather by the same substance.

If it were not for this very useful creosote, sleepers, poles and blocks would perish so quickly from decay that the expense of railway, telegraph and road repairs would increase enormously.

The creosoting has to be done in a very thorough way. Mere painting over with creosote is of little use if the protection it gives is to last for years. The method used is very interesting. Truck loads of sleepers are pushed into a long steel cylinder. The doors at the end of this are then closed and sealed, and all the air is sucked out. The pores of the wood are now quite empty, even of air. Next, the cylinder is filled with hot creosote under great pressure. The creosote sinks deep into the wood, filling every crevice, and making it quite waterproof

Wonders of Tar

Creosote is only one of very many things obtained from tar. Have you ever tasted saccharine ? It is a white powder hundreds of times sweeter than sugar. People whom the doctors do not allow to eat sugar sweeten their food with it. It is extracted from tar ; as, too, is the hard white substance with a rather pleasant smell, called naphthalene, which is put into drawers containing clothes and furs to keep moths, and other insects away.



The Science Museum, London.

MINERS' LAMPS OF THE OPEN TYPE

Times have changed since these lamps were used by miners, and, just as there have been great advances made in coal-getting and in safer equipment for miners, so has tremendous progress been made in the utilisation of coal. All the lamps in the unique collection seen above had exposed flames ; most of the lamps were made to hang up or to be supported by metal which could be driven into the coal face.

We clean our clothes with another tar product—benzene. Carbolic acid, which can burn the skin dreadfully, but is a very useful disinfectant, comes from tar. From tar also we get a great number of drugs. If you are a photographer and develop your own plates or films, you will use chemicals that once were locked up in coal.

The chemist has succeeded in winning from tar a whole host of perfumes imitating very closely the scents of thyme, hyacinth, mimosa, rose, lilac, musk, lilies, violets, heliotrope, jessamine and other flowers. And from evil-tasting tar he also extracts essences which deceive one into thinking that they came from cinnamon, almonds, peaches, cherries, vanilla, and so on.

Gas Council

PURIFICATION PLANT

Some idea of the complicated processes by which the many valuable products from coal are obtained during the manufacture of gas is given by this picture of the complete wet purification plant installed in recent years at a South London gas works

The Romance of Tar Dyes

About the middle of the last century, a young English chemist, William Henry Perkin, carried out some experiments with coal-tar in his little private laboratory. One day he obtained a black powder that stained things a purplish colour, to which he gave the name of "mauve." He sent a sample of the powder to a great firm of dyers to test. They were so pleased with it that Perkin set to work on extracting other dyes from coal-tar and discovered several new ones.

Perkin thus became the founder of the great industry of making artificial dyes from coal-tar. Hundreds of different colours have been found, very many of them by German chemists. Artificial dyes have largely taken the place of natural dyes extracted from indigo, logwood, madder and other vegetable substances, being cheaper and in some ways better.

The industry had become German to such an extent that, when the War of 1914-18 broke out, and we could no longer obtain dyes from Germany, a very difficult position was created. For without dyes the making of coloured woven fabrics of all kinds and printing colours would be brought to a standstill. British chemists had to buckle to and find out how to produce dyes in British factories They soon were turning them out in large quantities

We have said that it is difficult to get away from coal. The truth of this becomes more evident when we reflect that the clothes we wear, the curtains of our rooms, our wall-papers and a host of other coloured objects are dyed with substances derived from coal.

Oil from Coal

When coal is heated in the chambers, called retorts, to drive the gas out of it,

the heating may be carried to a point at which the greatest possible amount of gas is obtained. This would yield about 15,000 cubic feet of gas from a ton of coal.

But if less heat be used and we are content with less gas, we can obtain from coal a very useful quantity of oils of different kinds, which are made up of the same elements as coal-gas, differently combined.

It has been calculated that it would be *possible* to obtain 560,000,000 gallons of motor spirit and 3,000,000,000 gallons of fuel oil from the 150,000,000 tons of coal which we burn in Britain every year. And we should still have for our fireplaces and boilers about 100,000,000 tons of a fuel rather more gassy than coke, but burning readily, without smoke. At present we import hundreds of millions of gallons of petrol (motor spirit) and huge quantities of fuel oil, paying out millions of pounds of money in exchange.

Artificial Oil

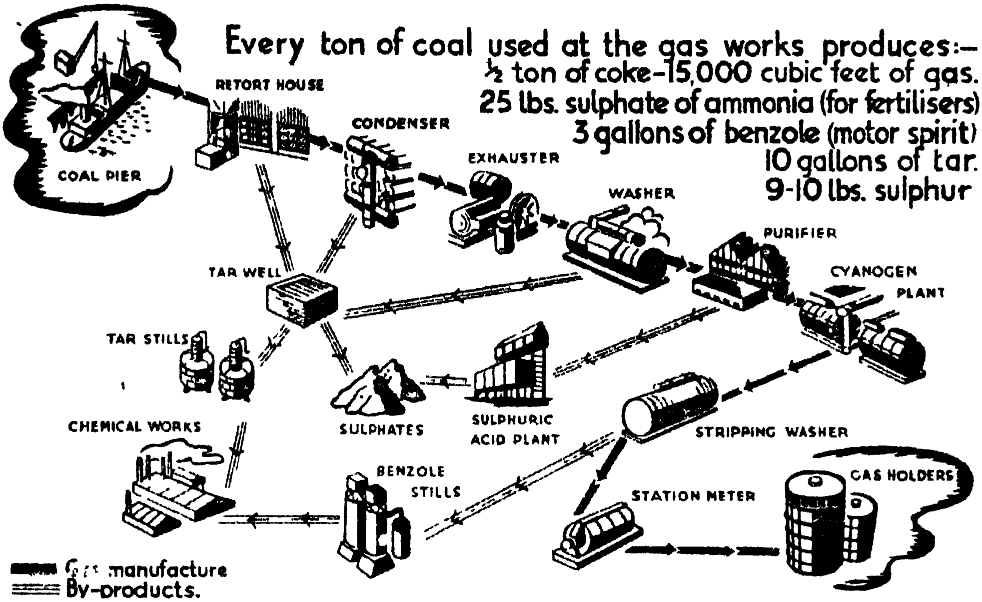
Even yet we do not know the full value of coal. It may have possibilities of which we hardly dream. Chemists are greatly interested in a process for getting oil from coal, not by distilling the coal, but by forcing hydrogen to combine with raw coal.

The process brings powdered coal and hydrogen-gas together in a very strong chamber, into which the gas is pumped until it has a pressure of about 3,000 pounds to the square inch. The chamber is heated from outside, and the pressure and heat between them produce a tarry liquid, somewhat like

Gas Council.

FOR FERTILISING THE GROUND

Sulphate of ammonia is well-known to farmers and gardeners as an important artificial fertiliser, and in this picture is seen a centrifugal machine for the separation of sulphate of ammonia for this purpose. At the gas works nearly 75,000 tons of sulphate of ammonia are made available each year to meet the demand both by agriculturists and by the chemical industry.



Gas Council

THE TREASURE IN COAL

In this diagram a general indication is given of what by-products are obtained from a ton of coal during its treatment at the gas works. Gas is the primary product, but the tar which is one of several by-products is also highly valuable since it provides the raw material for a large number of other industries. From it come disinfectants, preservatives, explosives, dyes, synthetic perfumes, food flavourings, and many other useful substances.

petroleum as it comes from the ground, and containing most of the coal in a new form. When distilled the liquid yields motor spirit, lubricating oil, fuel oil, and pitch.

It is at present perhaps too early to say whether the hydrogenation of coal, as this process is named, will be an entire success. But if it turns out to be all that is hoped for it, coal-fields will become a more valuable possession even than they are at present.

Paying with Coal

We have to import a great many things which we cannot produce at all ourselves, such as tea, coffee, cocoa, maize, tobacco, cotton, silk and zinc; or of which we do not produce enough to meet our needs, such as wheat, sugar and meat. These must be paid for largely in things exported. Chief among these are woven fabrics, steel, iron and coal. Coal was at one time sent abroad in very large quantities, amounting in 1913, for instance, to 73,000,000 tons. Owing to the war exports fell almost to zero, but great efforts are now being made to build up this important trade once again.

All the year round ships were loaded with coal in ports in South Wales, on the north-east coast of England, on the Humber, and on the Clyde. Many of the docks are equipped with special coal-loading machinery. A truck is lifted bodily with its contents, which are discharged through end doors into a shoot. After the war the export of coal practically ceased as we needed every ton in our own country.

It is hoped that this great export trade will be restored in due time, but at present strict economy in the use of coal is essential. In the past we have treated it in rather the same fashion as the Chinese of Charles Lamb's famous story treated their huts when they burned them down to roast pigs shut

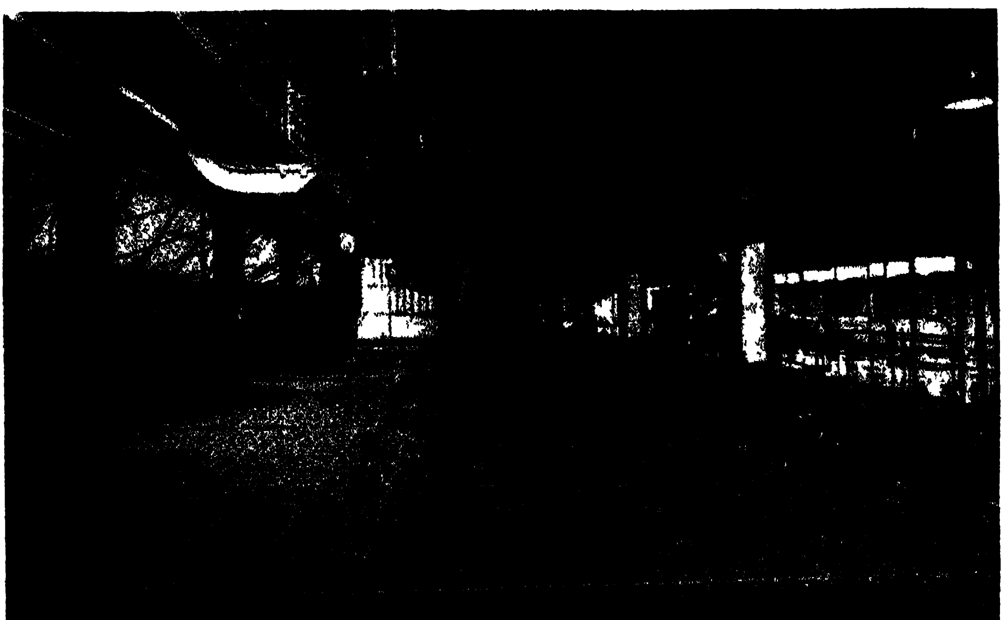
up inside them. Coal is a great deal more than fuel. By burning it in its raw state to get heat, we waste an immense amount of valuable substances. This is being realised more fully every year. Many people are working out methods of distilling coal which will give us a smokeless fuel while saving the precious things which we allow to go up our chimneys.

The importance of this aspect was stressed in the Report on Coal Utilisation Research in Great Britain, issued by the Parliamentary and Scientific Committee : "Our very life as an industrial nation depends upon maintaining supplies of energy and raw materials for manufacturing processes. Our climate obliges us to use immense quantities of fuel to warm our homes and places of work. There is no possible means by which we can offset the falling productivity of our mines except increasing the value and efficient use of the coal we are able to produce."

Nearly a Foot Deep

The gain will be twofold. We shall use our coal better, and at the same time get rid of a great deal of smoke which, while in the air, shuts out sunlight and is bad for our health, and, when it falls, fouls and damages everything upon which it settles.

We are told that the soot which falls in London alone during a year is enough to cover the 390 acres of Hyde Park nearly a foot deep. Experts also say that smoke costs the country over £40,000,000 a year in waste and damage to property. Things are not, however, so bad as they were, since more gas is used now than formerly for heating. But there is plainly plenty of room for improvement in this respect when you hear that in a test it was found that in one year dust, soot and other impurities equal to 563 tons to the square mile fell at Liverpool ; 390 tons in London ; and 237 tons at Edinburgh.

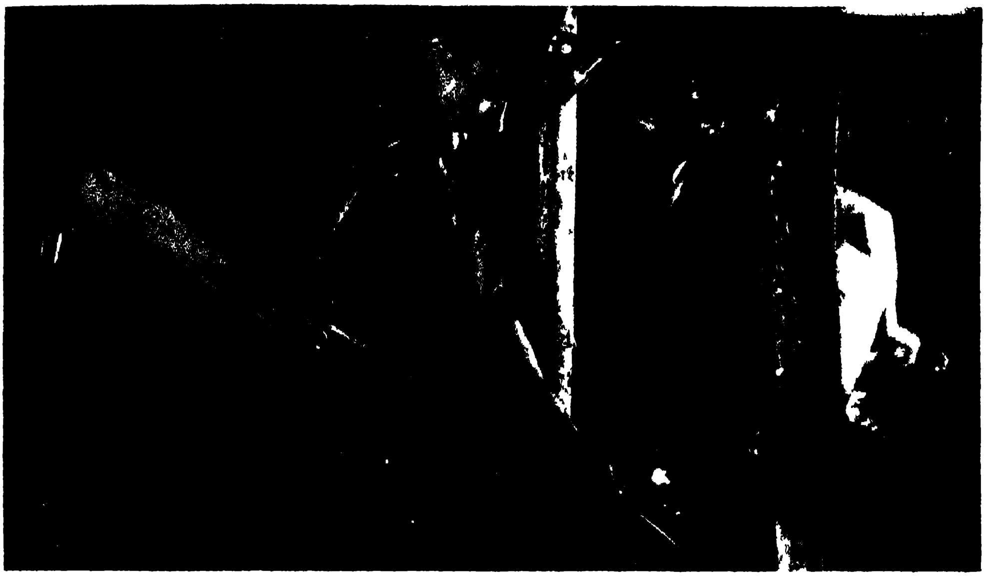


Woodall Duckham Company.

WHERE COAL IS CARBONISED

Here is another view taken in a large gas works. In the middle of the picture can be seen the chamber charging lids ; on the right are the gas offtake pipes. In the centre background is the coal charging car for the chambers The coke charging skip for the producers is in the left background, while the charging lids for the producers are on the extreme left.

A DAY IN THE LIFE OF A MINER



National Coal Board

WORKING AT THE COAL FACE

Crawling up to the coalface is hard on the knees and miners often wear protective pads In this picture a miner is "filling" coal—clearing away the coal which has been cut by the machines on to the conveyor which carries it along to the loading point where the tubs, controlled by the loaderman, are marshalled and filled before being hauled away on the first stage of their journey to the surface.

WE have read in previous chapters the story of a lump of coal: how it was formed under pressure through untold centuries from the forests and vegetation that existed before man had appeared on the earth. We have learned, too, something of the many different substances which this black rock from beneath the surface yields us to-day apart from its use as a fuel.

Now we come to the mine itself and particularly to the men who go down the deep pits where this buried treasure lies. The most prominent object at a coal mine is the winding or head gear, those twin wheels at the top of a steel structure which are usually visible for miles around. Over these big wheels run the steel cables which raise or lower the cages to carry their loads of men or materials between the surface and the workings underground.

There are always two or more shafts to any colliery. One of these two shafts is called the upcast shaft because it has a power-driven fan which sucks the used air out of the mine. The vacuum thus caused automatically draws fresh air in, down the other which is the downcast shaft. Around the bottom of the shafts an area of coal is left unworked and this serves as a pillar of support to the shaft and to the winding gear and buildings on the surface.

In the Lamp Room

Before going down the pit, the miner first calls at the lamp room. To-day this is usually lined with racks fitted with electric lamp accumulators which are being charged. On his head he has a black, light-weight helmet, and to the front of this his electric cap-lamp is fitted. A belt round his waist takes the accumulator, connected to the lamp by a length of strongly-

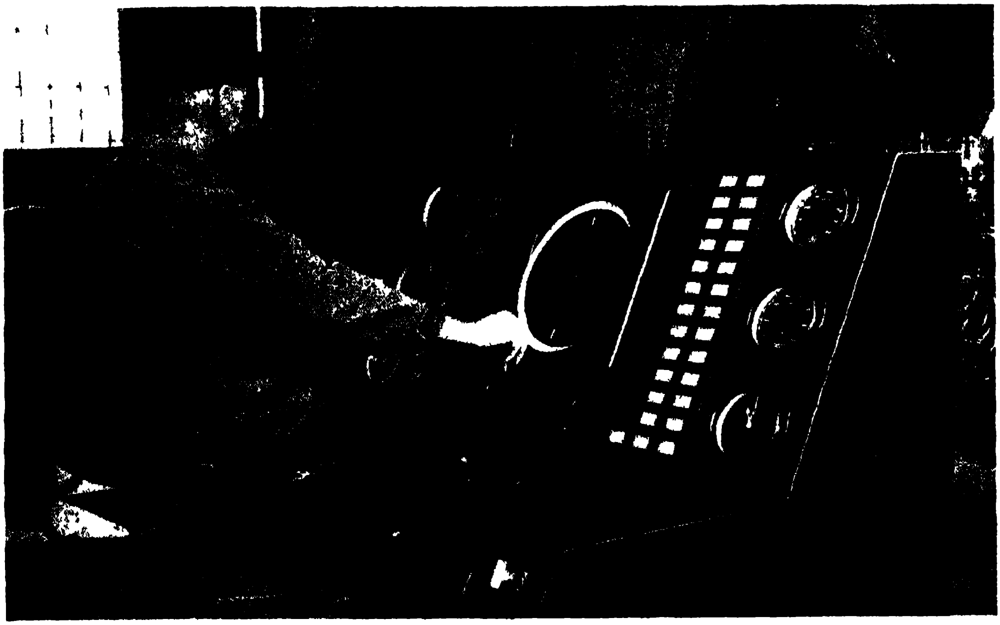
THE DEPUTY GIVES FIRST AID

One of the important underground officials is the deputy who is in charge of a district, and is particularly responsible for safety precautions in the mines. In this picture the deputy is seen after collecting his lamps as he receives his First Aid box before going on duty.

Photos: National Coal Board.

Safety and health are two aspects of the miner's life which receive constant study. Many mines now have a medical centre under a medical officer and with a trained nurse in attendance. Training in First Aid is given in all Divisions, and there are First Aid rooms in every mine. Here we see a coal-getter who has received a minor injury having attention in an underground office.

IN CHARGE OF THE WINDING GEAR



Above the underground workings is the winding or head gear and the operator in charge works to the signals from the pithead and is also in constant touch with the onsetter at the bottom of the shaft. A cage carrying men makes its journey at a slower rate than one carrying a load of coal tubs.

Photos National Coal Board.

Some idea of the winding gear itself is given in this picture. Apart from the men working down the mine there are highly responsible jobs for trained men on the surface, and not the least important are those of the operators in charge of the winding gear and the power driven fans which give full and adequate ventilation to all parts of the workings underground.

insulated flex. Certain men may take an oil safety lamp as well. The deputy, for instance, who is particularly concerned with the safety of the mine, uses a safety lamp when making his regular tests for gas in the workings.

Then from the lamp room the miner walks across to the big shed from the top of which the winding gear is seen, and in this shed are the gates of the shafts. Both tubs and men are carried up and down the shaft by two cages, most of which have two decks. Tubs and men, of course, are never carried in the same cage, and there is a different speed, strictly kept, for lowering the tubs or lowering the men. The cage carrying the tubs travels at a much faster rate than that used by the men.

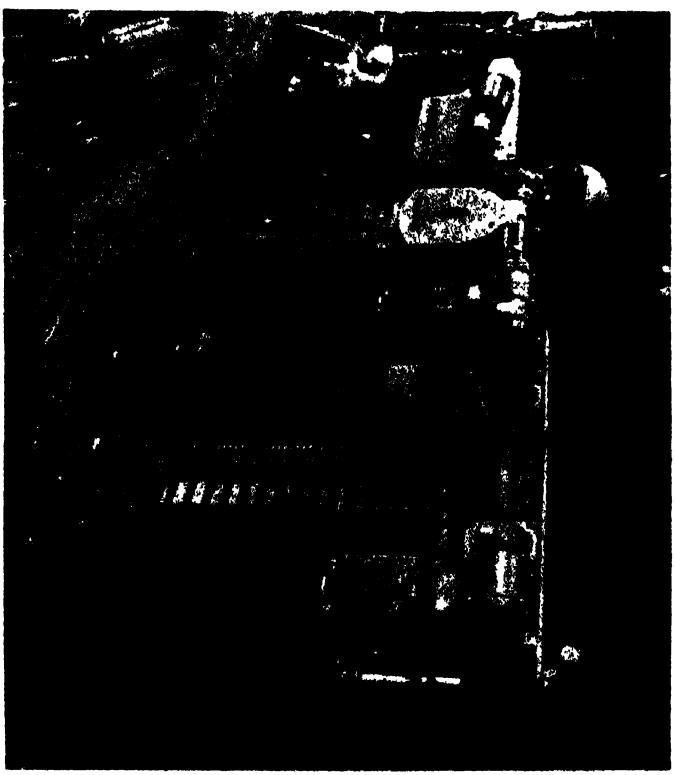
The bell signals are given to the engineman in control of the winding gear, and to the onsetter guarding the gates at the shaft bottom, perhaps 2,000 feet or even more below in the blackness. None of the men who enter the cage have either cigarettes or matches in their pockets.

There are of course many types of job in a modern colliery both above and below ground. Mechanisation has gone rapidly ahead and much of the hard work of cutting the solid coal seam is now done by machines. Plenty of hard work remains to be done, however, and coal-getting is still a "man's job" in every sense of the term.

Down the Mine

Inside the cage the men who are going down grasp the bar above their heads and the final bell signals are exchanged. Then the cage begins to sink, gathering speed as it descends, but gradually slowing down on the last stage till it lands gently at the bottom of the shaft. Here one steps out into a brick or concrete-lined hall, well-lighted, and from this runs the "main road" as the principal tunnel into the mine is called. At intervals along this main road are telegraph signal points to communicate with the engine man in control of the hauling of the tubs. There are telephones, too, in communication with every part of the mine through the central telephone exchange at the surface.

This main road is also a railway, and



National Coal Board.

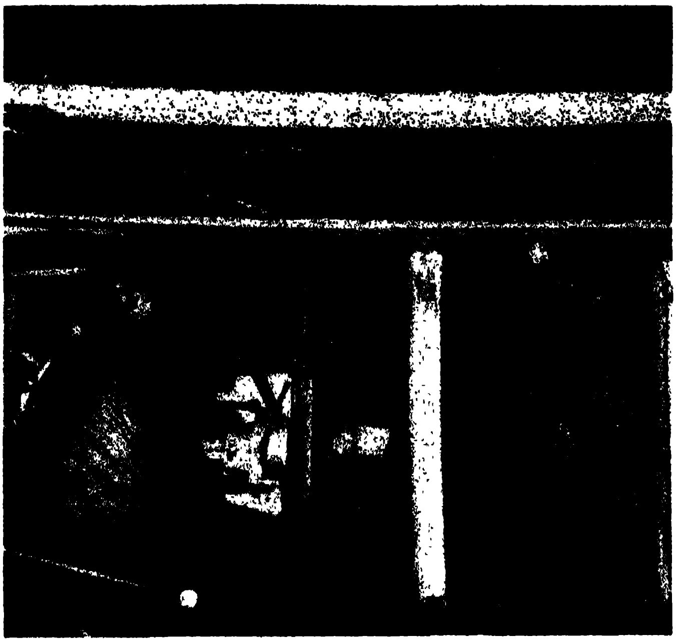
A MODERN COAL-CUTTING MACHINE

Both above and below ground expert mechanics, fitters and electricians are employed in installing and servicing the coal-cutters, loaders, conveyors, ventilating fan motors, electric drills, etc. Here we see one of the coal-cutting machines being serviced in the workshop.

DRIVING A NEW ROADWAY

National Coal Board

There are about 14,000 miles of underground roadways in the coal mines of Britain, and the work of driving new roadways or extending old roads is carried on steadily as the mine is developed. This photograph shows part of a modern drill rig, which is mounted on a truck. High-speed drills, carried on booms, bite into the solid rock which is later brought down by explosives.



SETTING SCREW JACK PROPS

Mechanisation in the mine has not robbed coal-getting of all its hard work, nor has it yet made it a clean job. Here we see miners at work setting screw jack props behind the cutter of a Meco-Moore Cutter-Loader.

work goes on throughout the 24 hours and is divided into three main shifts, each working 7½ hours, though the men on the shift may be up to another half-hour below ground, according to the time it takes to raise them all in the cages.

Coal-getting depends on team work. As the coal face advances each day the rocks forming the roof subside towards the floor. Men on the afternoon shift build "packs" — piles of tightly-rammed débris encased in walls built of larger pieces of stone —at intervals. At the same time the roadways are being ad-

both full and empty tubs are on the move to and from the cages all the time. The noise can be imagined. Where there is a long journey from pit bottom to coal face the men may do the first part of their journey in one of these trains or tubs. They may have to go a couple of miles or more to the place where they are actually working.

At first the road may be ten feet high and steel girders support the roof and sides which are bricked or concreted. But gradually the tunnel narrows and the tidy sides give way to rougher planks.

In most collieries

Photos: National Coal Board.

IN THE PITHEAD BATHS

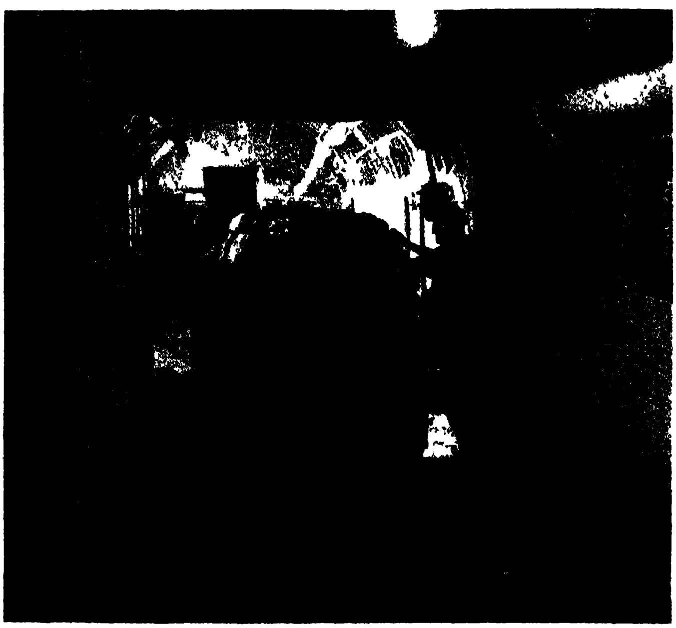
At the end of his shift the miner gets rid of his grime in the pithead shower baths before going home. Each man has an aluminium locker for his clothes to which hot air is supplied by a duct.

vanced, and girders are set to support the roof and the sides of the roadway. Probably the men on this shift dismantle the conveyor and reassemble it in a path closer to the face.

As the men on this shift complete their work their places are taken by the men on the night shift. On this shift the coal is cut, the rows of props and bars that supported the roof on the previous day are moved forward and the conveyor in the " main gate " is extended so that the coal from the face conveyors which have now been moved, possibly a yard and a half forward, will still pour on to it.

A PIT PONY AT WORK

Gradually the pit ponies are being replaced by electric traction or diesel locos There were still some 17 000 ponies at work in the pits in 1951 They go down as four-year-olds, and often stay for between ten and twenty years



Photos National Coal Board

REPLACING THE PONY

Other methods of transport have invaded the mines just as the horse-drawn 'buses in the streets have given way to motor transport Here we see one of the diesel locos at Hatfield Main Colliery coming in to its underground garage.

Two men normally work with the coal-cutting machine. One is in charge of the operation of the machine, a second clears up the small pieces of coal and dust made in cutting and inserts wedges into the cut to keep the coal from falling too soon. Other men remove and re-set props as the machine moves along the face.

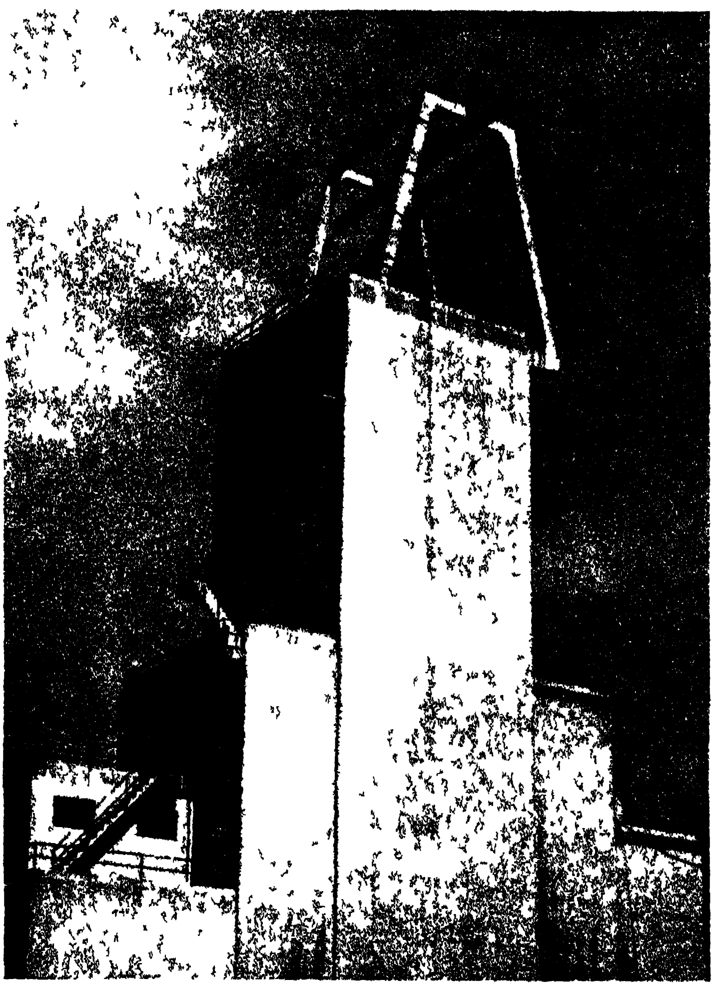
Other men bore holes, usually about 2 inches in diameter, into the coal. In these shot-holes explosives will be put to blast down the coal. One man will operate a compressed air or electric drilling

machine, boring the shotholes along the face. One or two shotfirers will later insert a charge of explosive in the holes, fill up the rest of the hole with clay or "stemming" and blast down the coal. These "breaking in" shots enable the colliers who go to work on the next shift to get the coal.

Working at the Face

Usually the men on the morning shift "get" the coal at the face, while other men work the haulage to transport the coal from the face to the shafts. At the pit bottom are men who load the full tubs into the cages, as well as pushing out and sending back to the workings the empty tubs that return down the shaft.

There may be thirty, or even twice as many, employed on a longwall face "filling" coal, the number depending on its length. They set supports to secure the new roof as it is exposed The coal from the face conveyors is fed on to the "gate" conveyor which carries it along the "gate" to the loading point where the tubs, controlled by the loaderman, are marshalled and filled The tubs pass along the roadways where the boys and men working on the haulage couple them up into trains and clip them to the haulage rope.



National Coal Board.

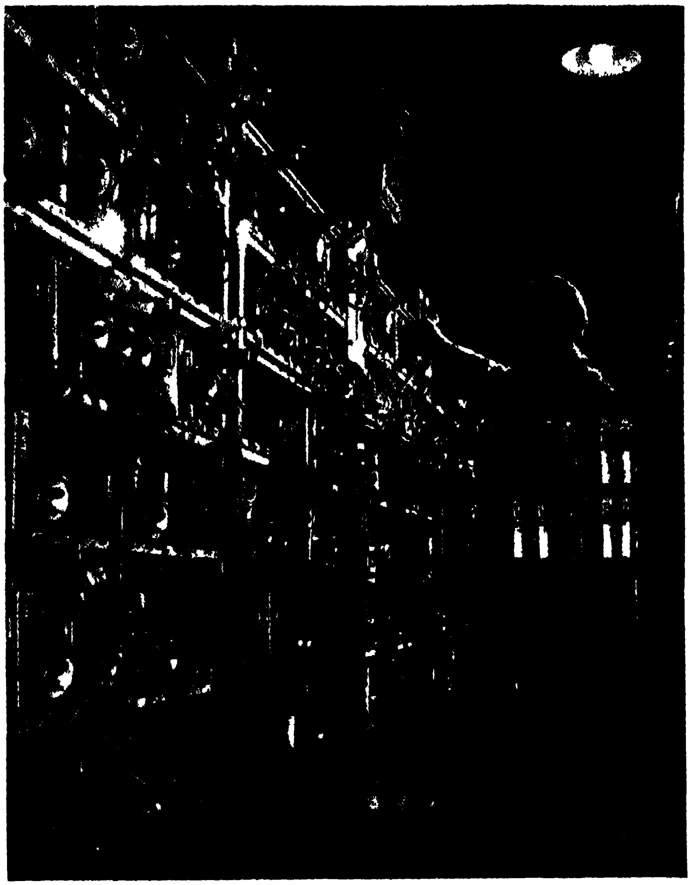
PIT HEAD GEAR AT A MODERN COLLIERY

In 1945 a Government Committee of Mining Engineers was appointed and later recommended a big programme of reconstruction and development in our coal mines During the past few years a great deal has been done to modernise our collieries and this photograph shows the up-to-date pit head gear at the Mosley Common Colliery in Lancashire

A haulage engineman looks after the engine which keeps the haulage ropes moving, pulling the full tubs away from the face and drawing the empty tubs back towards it. At a junction of two or three roadways the haulage workers may have to detach the trains from one rope and attach them to another. At some junctions the work may be supervised by a "corporal" whose job it is to see that the track is properly laid, that supplies needed at the coal

face, such as steel arches, pit props and bars, timber and machinery, all reach their right place, and that the movement of the tubs is not held up in any way.

The pit pony is still used in some mines, but gradually the numbers employed below ground are being reduced. In 1951, however, there were still some 17,000 ponies working in our mines. Just as modern methods and modern ideas have improved the working conditions of the miners themselves, so have modern standards improved the conditions under which the pit ponies of to-day carry on with their work below ground.



National Coal Board

IN THE LAMP ROOM

Before going down the pit the miner calls in at the lamp room On his head he wears a black, light-weight helmet, and to the front of this the electric lamp is fitted. The accumulator is hung on his belt and is connected to the lamp by a length of strongly insulated flex.

Screening and Washing

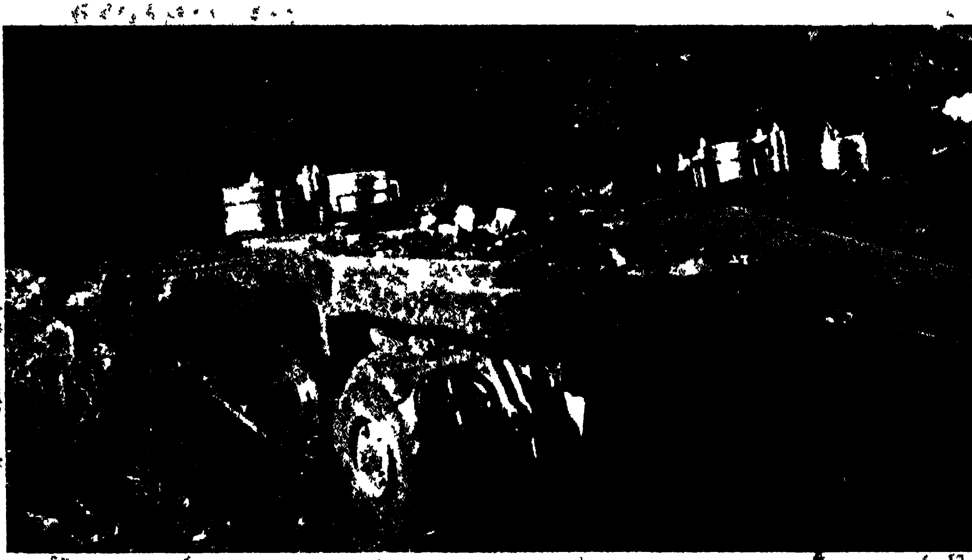
When the cage of full tubs reaches the surface, the "banksman" pushes the empty tubs into the cage and the full ones out at the other side, though in some mines this is often done by pneumatic rams. The coal in the tubs passes to the screens where it is tipped out and sorted into sizes. The small coal goes to the washery where it is cleaned and again sized. This washing plant is a very important part of the equipment of most collieries. A stream of water is passed through the mixture of small coal and rubbish and drives the coal away as it is lighter than the stone, slate, etc. which is left behind.

Research work and experiments are being carried out continuously and experts believe that in various branches of the industry big advances will be made in the next few years.

Roughly about half the total number of men employed underground are engaged in the actual task of getting the coal and putting it in the conveyors and tubs which take it away. At the time of the Reid Committee, whose report was published in 1945, it was considered that our old-fashioned haulage system was mainly responsible for keeping down the output of the mines. Since then the task of installing coal-cutters, mechanical conveyors and haulage locomotives has been a high priority and

THE MAN WHO FIRES THE SHOT

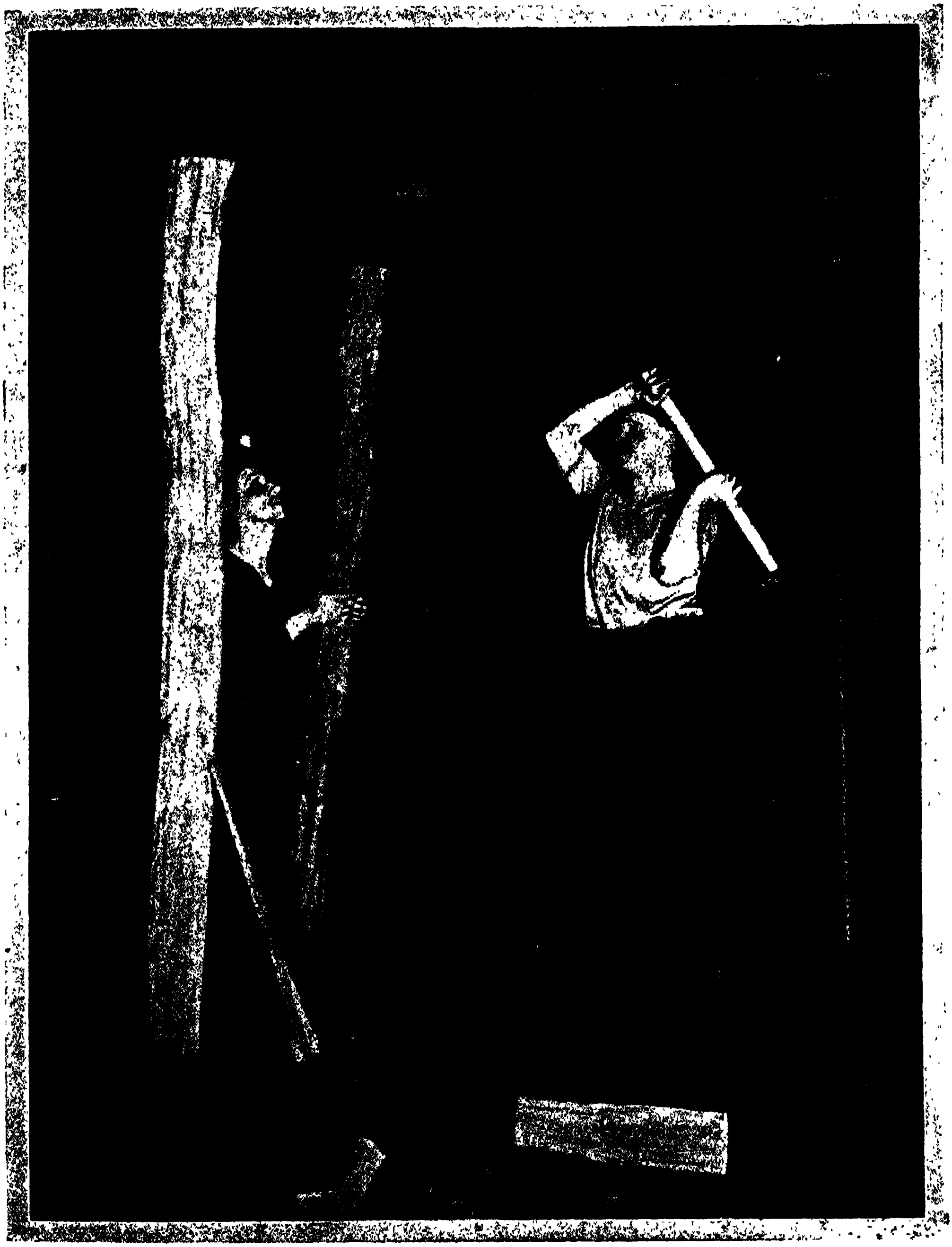
One of the most responsible jobs in the mine is that of the man known as the shot firer He carries all explosive charges in a locked canister to which there is only one key which never leaves his possession Here he is seen unlocking the canister before fixing and firing the shot to dislodge the coal



Photos Mirror Features

The shot has been fired and has done its work successfully, bringing down some thirty tons of coal In some mines the mechanical loader moves forward and draws the coal into the electrically-driven shuttle-car In others the coal is filled on to conveyor belts and later transferred to wagons

A SAFE ROOF OVERHEAD



Mirror Features.

All the underground galleries in a coal mine must have adequate support for the roofs. In main roads near the shafts brickwork or metal rings similar to those used on underground railways may be used. Nearer the coal face where the galleries are smaller wooden pit-props are used to support steel girders. The pit-prop is cut to the required length, then hammered into position, wedges being used when necessary. It is essential that the steel bars supporting the roof shall be exactly horizontal.

has already brought about a great improvement.

Electricity to-day does all the winding and hauling in many mines, and the pumping in almost every mine. For every ton of coal that comes to the surface several tons of water may have to be pumped from the mine to the surface. In most mines the pumps never cease their work throughout the year.

Finding a Fault

On the whole the daily round of the miner does not continue uninterruptedly on the same job for so very long. Apart from the different tasks which are undertaken by each shift there may be changes at the coal-face itself. One day a last strip of coal is got from the face to leave a wall of solid rock confronting the next shift. A "fault" has been encountered; a great crack in the earth's crust breaking the continuity of the layers of rock, the edges of which have slipped bringing the coal on one side of the fault above the coal on the other side. The seam may continue at a higher level above the roof of the old face, or at a lower level, below the floor.

Drifts may have to be driven through the rock to get at the displaced seam so that coal-getting can begin again as soon as possible. The transport of the necessary materials and machinery, laying the sleepers and rails, track for new haulages, all these are jobs which the miner is called upon to do when necessary.

There is quite a wide variety of jobs, too, among the men who work underground. The Coal Cutter operates the coal-cutting machine, which is driven by compressed air or electricity; the

National Coal Board.

BOYS LEARNING THEIR JOB

Boys who enter the mining industry go first to a Group training centre which serves a number of collieries. Their training here lasts for 16 weeks, after which they go to their own colliery where they gain practical experience under their own training officer. Here we see a group of trainees down the mine where they are being taught how to clip the tubs to the haulage rope.

National Coal Board

THE DEPUTY TESTS FOR GAS

In some coalfields the deputy is known as the "examiner," or "fireman" He is responsible for the safety of his district, and among his tasks is that of making tests for gas One of the best methods is the use of the flame safety lamp When the flame is turned down to a narrow line on top of the wick, a halo, or "cap," is formed above the flame if firedamp is present A trained man can detect as little as $1\frac{1}{4}\%$ of firedamp

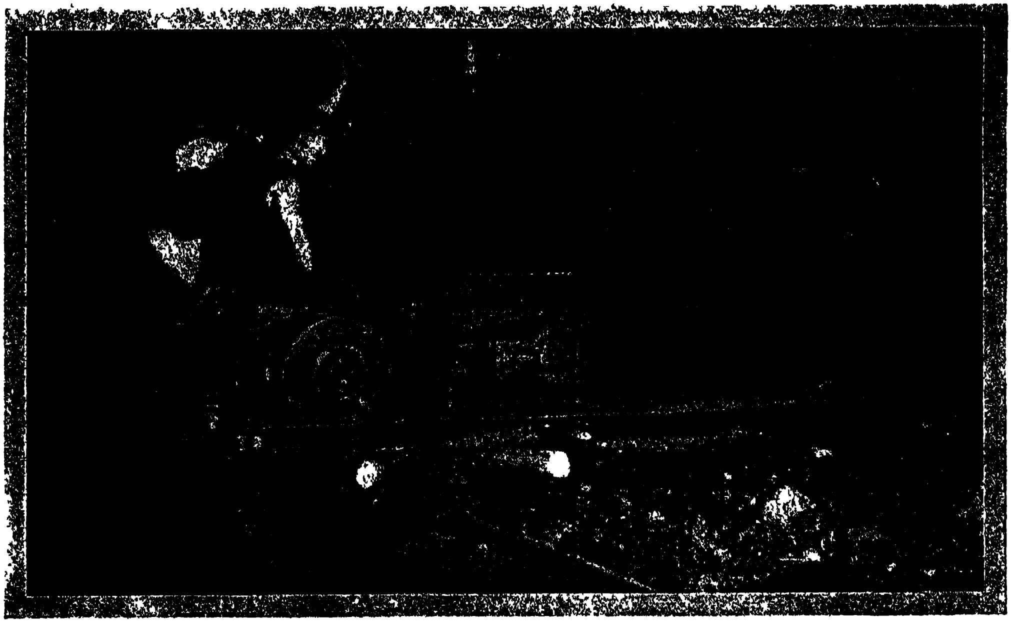
Coal Hewer brings down the cut coal from the coal-face, either with a hand pick or by mechanical pick, while the Ripper cuts away rock over the seam to enable the roads to be made, levels roadways, and sees to supporting timbers or steel arches. On this work he uses power drills and explosives when necessary.

The train of tubs which carry the coal away from the coal-face is drawn by the engine under the control of the Haulage Engine Man, while there are Electricians and Fitters working down the mine to install and service the coal-cutters, loaders, conveyors, ventilating fan motors, electric drills, and other underground machinery.

On the staff side there is the Agent who exercises technical and administrative control over two or more collieries, while the Colliery Manager looks after and directs the day-to-day work of his own particular mine. In charge of all underground workings during his shift is the Under Manager, while the Colliery Engineer is responsible for the maintenance of the mechanical and electrical equipment and the Surveyor keeps all the plans of the workings up to date.

The Overman is in charge of a section of the underground workings, and the Deputy looks after a district and is particularly concerned with safety. In some coalfields the Deputy is better known as the "examiner" or "fireman." He examines the district at

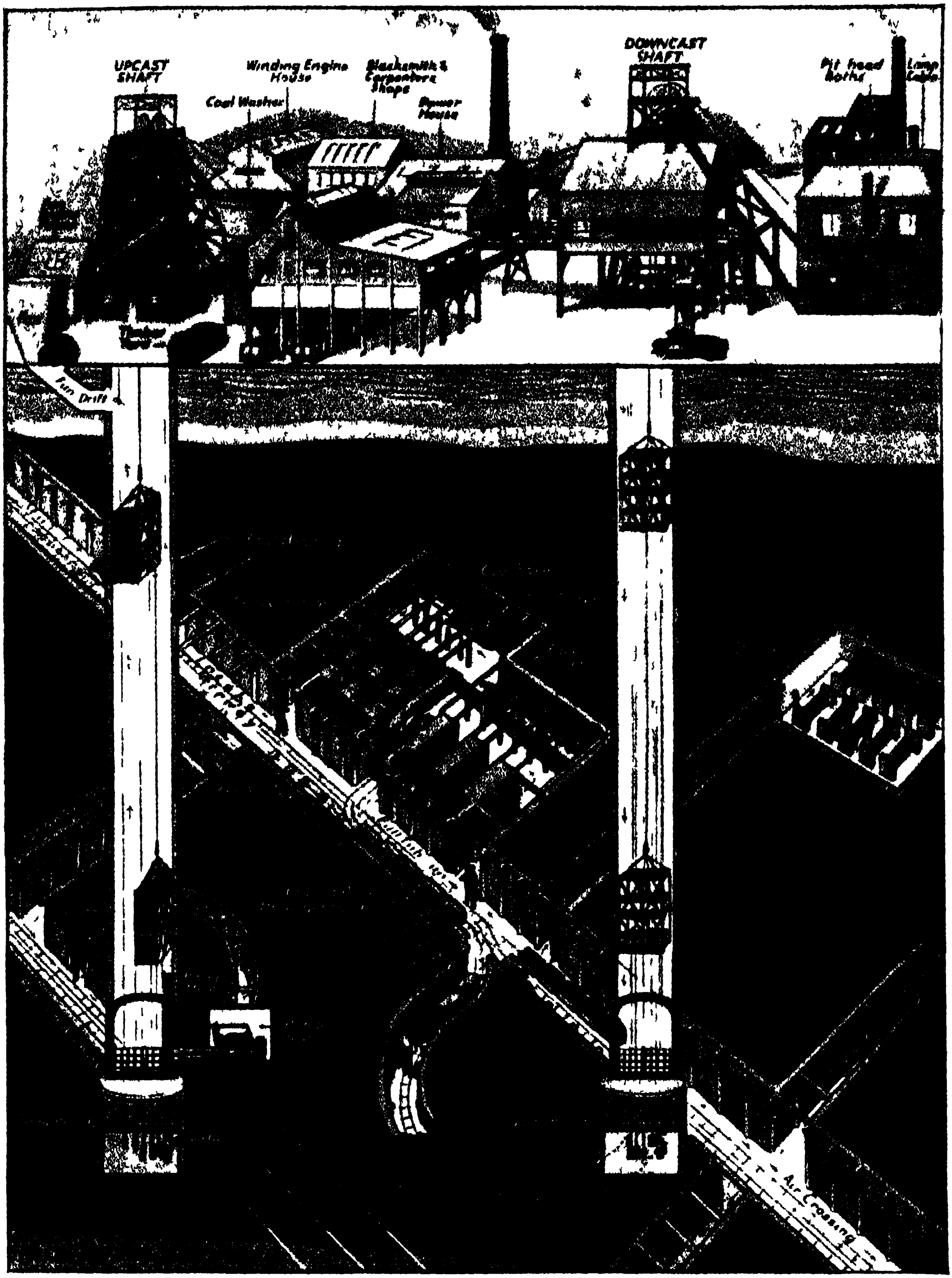
THE COAL-CUTTER AND THE SHUTTLE-CAR



In the Whitehill Colliery the most remote coal faces are over three miles from the pit bottom, and the mine itself is 2,750 feet underground. It is fully mechanised, and our photograph gives a view of one of the electrically-driven Sullivan Coal-cutters which cuts into the bottom of the coal face to a depth of about six feet.

Photos: Mirror Features.

Once the Coal-cutter has done its part the work of getting out the coal is very much easier. In some modern mines it is loaded into the shuttle-car and driven off to the conveyor belt. There is no pony or manual haulage in this colliery and the shuttle-car seen here is being driven by a young miner.



ABOVE AND BELOW GROUND AT A COLLIERY

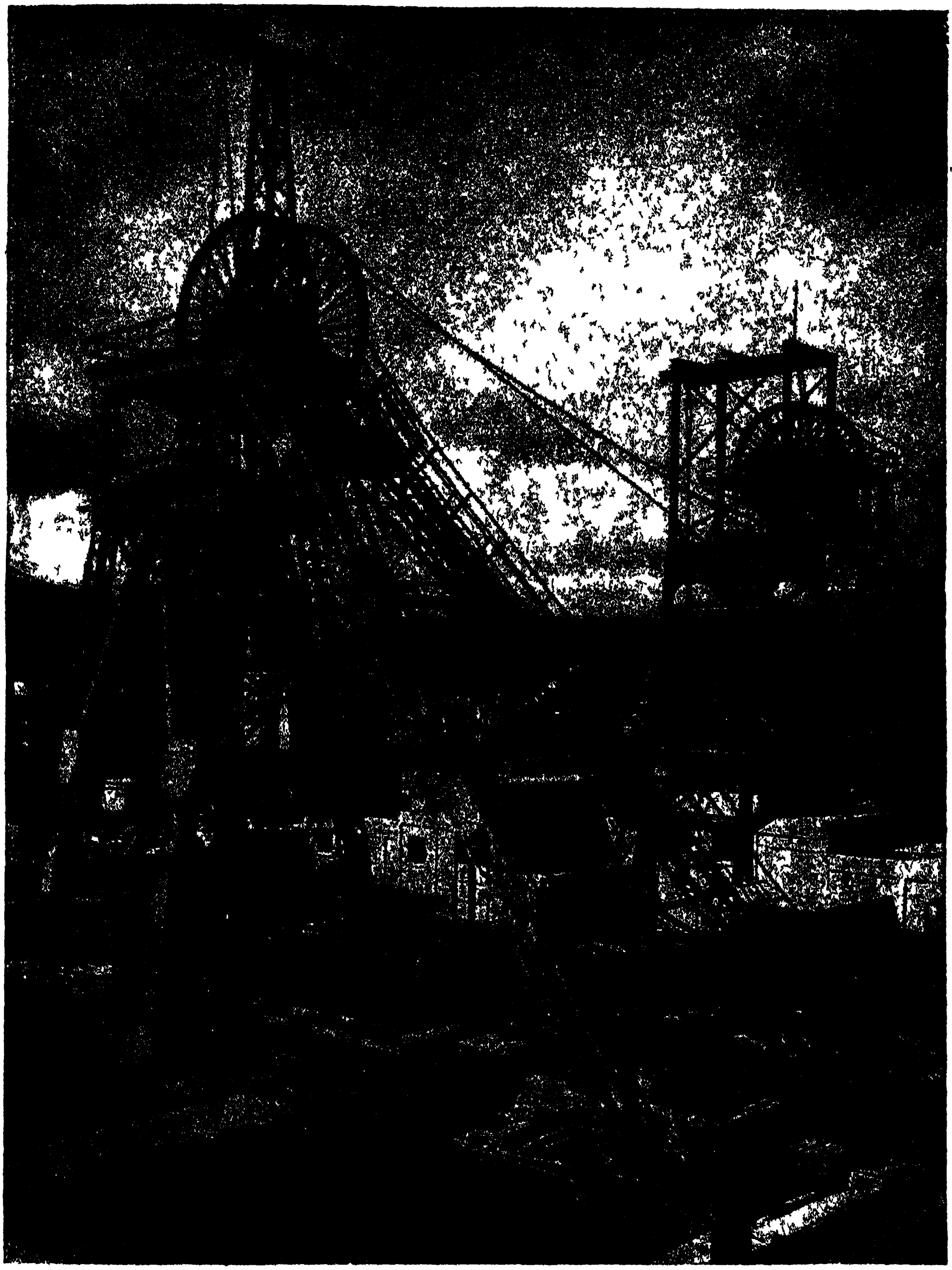
On the surface a coal mine has its power-house, screenings, railway sidings and gear for the shafts which give access to and egress from the pit. Fresh air for underground workers is drawn into the depths by way of the downcast shaft, circulated through roadways and along many passages, until it is withdrawn by means of the upcast shaft. Though tubs or trains may be drawn along the main roads by steam or electric haulage engines, ponies are still used near the coal face, their stables being always the subject of special care. Note the cages in the twin shafts.

[illegible]

A BLAST FURNACE IN ACTION

A blast furnace in an ironworks is a great stove through which a current of air is driven to bring the ore, flux and coke with which the receptacle is charged to glowing heat. In this process the purpose of fireside bellows is carried into effect on a colossal scale. Thus air from a reservoir passes through a heating stove and then enters the furnace from below. Gas generated in the furnace is used to operate the blowing engine; and, as we see above, molten metal trickles like water to the furnace hearth from whence it is directed into troughs.

A NEW MINE IN SOUTH WALES



"*South Wales Argus*"

Many collieries have been reconstructed and remodelled in recent times A number of new collieries have been sunk, while small pits nearing exhaustion have been closed Among mines reopened and remodelled in recent years is one at Nantgarw in South Wales which produces a type of coal particularly suitable for carbonisation, producing gas, coke, and the various products of gas manufacture. The photograph shows Nantgarw during reconstruction

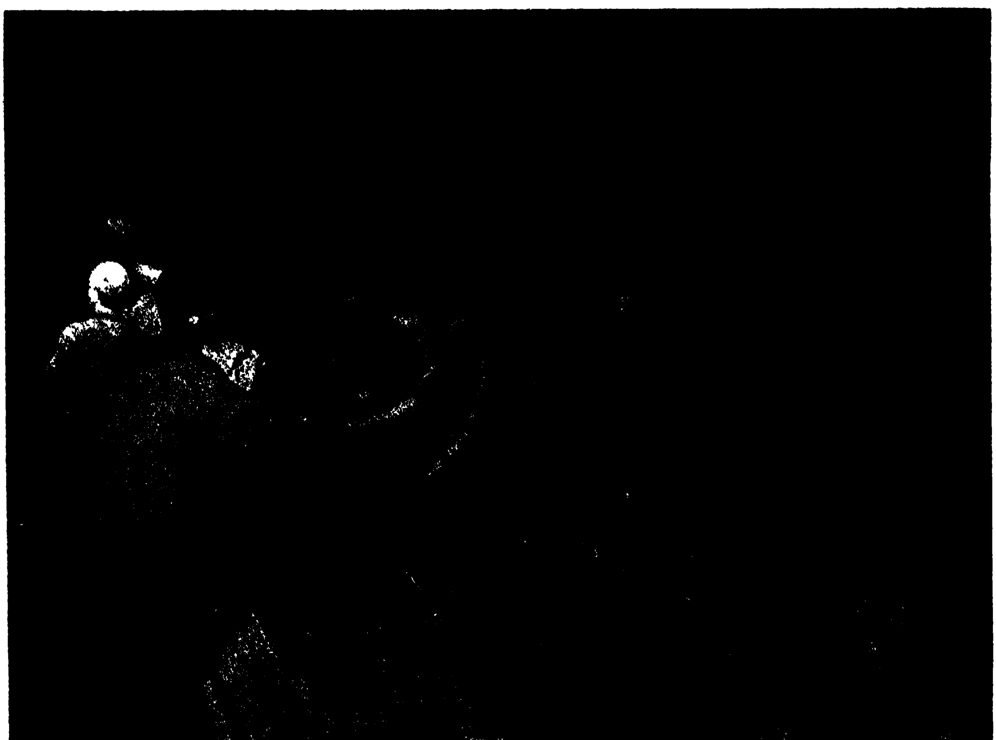
least twice every shift to see that everything is in order and at the end of his shift he compares notes with the incoming deputy before going off duty and making his report to the manager. In testing for gas the " deputy " uses a flame safety lamp. He calculates the amount of firedamp from the height of the flame.

Testing for Gas

There are many other jobs at a colliery: shaftsmen, boilerman, storemen, lampmen, pumpmen, safety officers, training officers, dust suppression officers. Then in the workshops above ground fitters are kept busy in repairing and maintaining the great variety of mechanical devices used, while in the blacksmiths' shop the tools are sharpened and tempered, steel arches are repaired, and work which requires oxy-acetylene welding is carried out.

The training officer at the colliery, who is responsible for the welfare of the workers during their first six months at the mine, is able to give advice to any lad about the particular job for which he is best fitted. There are many opportunities for young men to take courses of advanced study to qualify them as technicians, undermanagers, and surveyors.

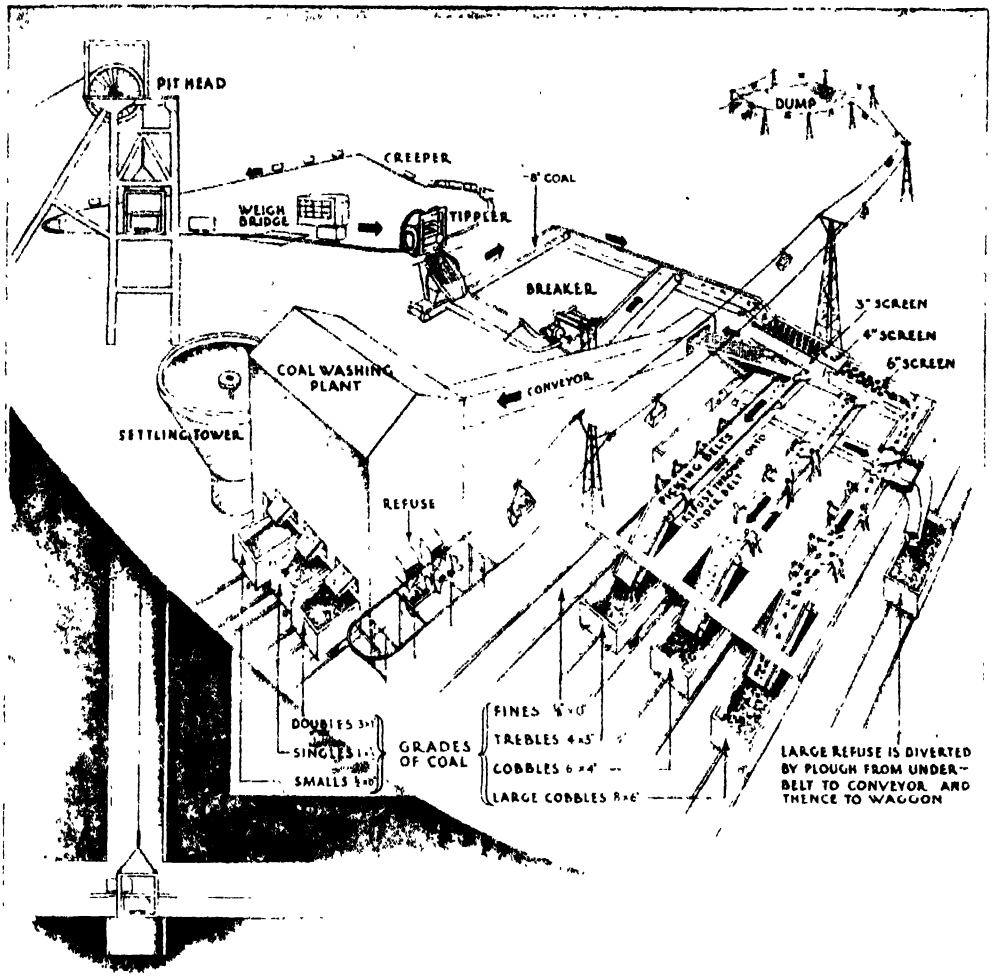
As long ago as 1920 a " Miners' Welfare Committee " was set up by Act of Parliament, and a levy was imposed on every ton of coal to provide the money. Much of the money has been used to build pithead baths so that the miner can leave the pit dirt at the colliery and travel to and from work



National Coal Board

WORKERS AT THE SCREENS

In the picking sheds the large coal is sorted, any foreign matter such as stones, shale or slate being thrown out by experienced men as the coal passes over an endless chain of trays known as screens The position of these screens is shown in the diagram of the washery on the opposite page



National Coal Board.

WHERE COAL IS SCREENED AND WASHED

The big brick and steel structure which is a prominent feature at many collieries is known as the washery. When the coal comes from the pit it is a mixture of large and small pieces and a certain amount of rock and dirt. This mixture has to be cleaned and sorted, and in the above diagram a general idea is given of the various stages through which the loads from the mine now pass. The smaller coal is tipped into tanks of water which are kept agitated. The stone and other impurities sink while the small coal floats off and over a miniature weir to grids, where it is dried.

clean and well-dressed. Apart from these pithead baths, over 1,000 welfare institutes and outdoor recreation schemes, as well as nearly a score of convalescent homes, have been provided.

Present coal-cutting methods result in considerable quantities of coal, amounting to about 10%, being reduced to dust or very fine, dirty coal. How to convert this into serviceable fuel has been the subject of recent experiments. Methods have now been devised whereby this dust can be efficiently cleaned and converted into top quality fuel in the form of briquettes. In due time this should lead to the addition of several million tons of coal to our yearly production of fuel.

There is no industry more important to Britain than coal-mining. Nearly 700,000 miners are employed and more

are wanted to increase the output which amounted in 1952 to over 212 million tons of deep-mined coal. A coal-miner's job may not have the glamour of certain other callings, but a great deal has been done in recent years to make the conditions under which the miner works as pleasant as possible.

In the old days a boy who went into the mining industry usually learned his job from a relative or older friend who was anxious to help him. Nowadays, with mechanisation changing the methods of working, this family party plan, excellent though it was, has almost completely disappeared.

Realising this, regulations have been introduced to ensure the proper training of all new entrants. A boy goes first of all to a Group training centre where films, charts and pictures are used to explain how coal is brought from the pit face, how the mine is ventilated, and many other details, including demonstrations on how the job is done. Part of his time is spent in school where English mathematics, mining science as well as physical training are among the subjects taken. Boys spend sixteen weeks on this part of their training, while older men take a shorter course.

After leaving the training centre the new mine-worker goes to his own colliery. His training at the coal face lasts for at least sixty days, and the new boy learns from a trained worker the best way of doing the job.

National Coal Board.

BY-PRODUCTS FROM THE COAL MINE

On an earlier page is a picture of work in progress at the new mine at Nantgarw in South Wales. In this picture we have a view of the coke ovens and by-products plant at Nantgarw. It will deal with some 1,500 tons of coal daily, yielding 1,100 tons of coke as well as 18 million cu. feet of gas for Cardiff and neighbouring towns, 4 tons of concentrated ammonia and 3,000 gallons of benzole.

ALL ABOUT IRON

British Iron & Steel Federation

AN IRONSTONE QUARRY IN NORTHAMPTONSHIRE

This photograph shows the first stage in the production of iron and steel The big mechanical shovel removes the " overburden " to expose the ore The lower shovel digs out the ore and loads it into wagons

IRON and steel are inseparable from our everyday life whether we are awake or asleep We sleep on beds with steel springs On rising, we wash ourselves with water pumped through iron mains, and, if necessary, remove whiskers from our faces with a steel razor. At breakfast, the milk on our porridge or in our tea may have travelled over a hundred miles the previous night in a steel tank-wagon over steel railway lines and hauled by a steel locomotive. Then we go to school or to work, perhaps on a bicycle which is practically all steel except for the rubber tyres and leather saddle The streets may be lined with iron lamp standards, there may be steel tramlines let into the roadway. Perhaps on the way we pass under a steel railway bridge. Cars and buses pass, made up almost wholly of iron and steel, except for the tyres and upholstery. Electricity and gas supplies depend upon iron and steel, and much of our food is imported from overseas in steel ships and cooked on stoves and in ovens made of iron Iron and steel never cease to affect us intimately throughout the day until the steel bed-springs claim us again at night

So important are iron and steel, that economists compare the material wealth of different nations by estimating how many pounds of steel are consumed in them every year for every one member of their populations.

Iron and steel are very closely related, but the words are not just different names for the same thing. There are three kinds of iron and, to understand the relationship between these and steel we may draw up a " family tree " like this—

IRON ORE

PIG IRON

SCRAP

STEEL CAST IRON WROUGHT IRON

Cast iron, wrought iron and steel are finished products, that is to say, materials from which useful articles (machinery, etc.) are made. Iron ore is the raw material which occurs in Nature, while pig iron and scrap are intermediate products, that is to say, they are of no use in themselves except as a means of producing iron and steel.

In telling the story of iron and steel we shall first examine iron ore and see how pig iron is produced from this. Then we shall see how cast iron and wrought iron are produced and what they are used for. Finally, we shall see something of the more difficult and costly business of making steel, of which there are a great many varieties, and the kind of things it can do for us

Iron Ores

Iron does occur in certain parts of the Earth as "native" iron, that is iron not in chemical combination with any other element, but the amount of such iron is so small and in such awkward places that it is not worth while to collect it and use it for any purpose. The sources of all our commercial iron are *iron ores* which for the most part are oxides of iron, *i.e.*, iron combined with oxygen and, to a lesser extent, iron carbonate, a compound of iron, oxygen and carbon.

BISRA

AN EARLY BLAST FURNACE

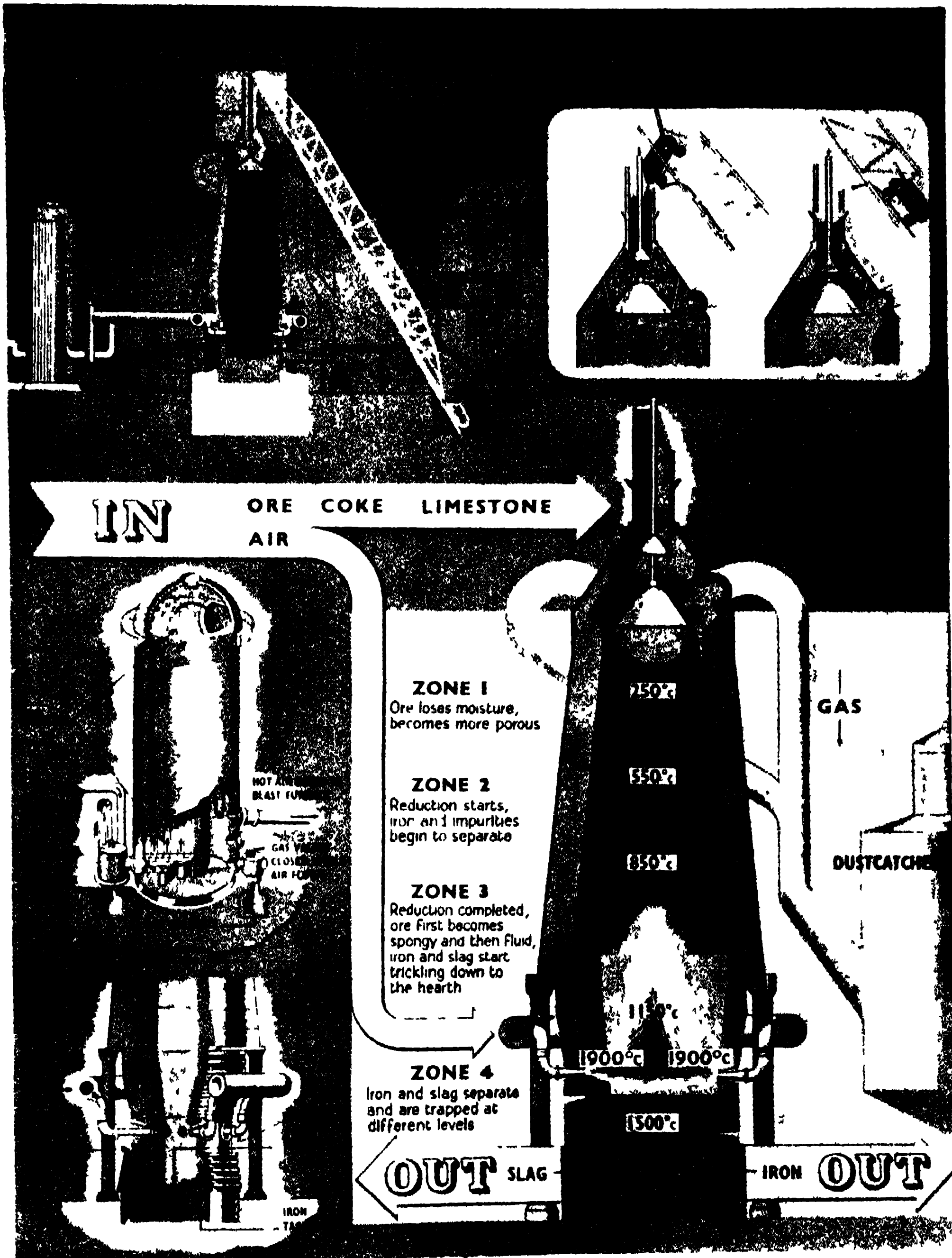
Sussex was at one time the great iron-smelting district of England This picture, from an engraving on an old clock-face, shows an early eighteenth-century blast furnace in the Weald of Sussex

The richest of these ores which contains over 72 parts of iron in 100 of ore is called *magnetite* because it is magnetic and is mined extensively in Northern Sweden at Kiruna and Gellivaare. There are other deposits in various parts of the world.

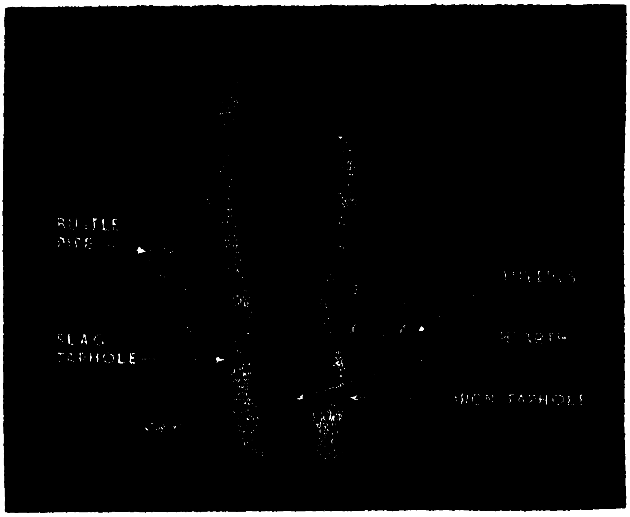
Next richest is *hematite*, which is red-coloured and is named after the Greek word for blood. It contains 70 parts of iron per 100. It is mined in Cumberland and North Lancashire and in South Wales. Enormous deposits have been worked in the American state of Minnesota at Mesabi on the western tip of Lake Superior, and further large deposits are being explored in Brazil, Venezuela, Labrador, etc. It is also mined and exported from Spain (Bilbao being the chief port) and N Africa.

Limonite is similar to hematite but contains chemically combined water, making it a "hydrated" ore and therefore less rich. It is frequently found in marshy places as "bog iron ore" and derives its name from the Greek word for meadow. It contains 60 parts of iron per 100, and is extensively mined and smelted in Alsace-Lorraine (France) where it forms a large part of the great "Minette" ore deposit.

THE MODERN BLAST FURNACE



This diagram illustrates the Blast Furnace of to day, and its working is described in these pages The circular tower is about 100 feet high and up to 27 feet in diameter across the bottom. The top of the furnace is quite cool while the hearth at the bottom is at white heat As the smelting proceeds the molten iron collects in the hearth. The impurities which have combined with the limestone to form a molten mass, known as slag, are easily removed



BISF

A CLOSER VIEW OF THE HEARTH

In this diagram a closer view of the hearth of a blast furnace is given.

Possibly, the discovery came when lumps of exceptionally rich ore were for some reason placed on a fire and the wood, burning down and forming charcoal, smelted them at least partially. Other people believe that iron ore may have found its way into an old pottery kiln, for we know that the art of "firing" earthenware is extremely old. At all events, there is definite evidence to show that iron was smelted as long ago as 1400 B.C. and possibly even before then.

The early iron smelters obtained iron by heating lumps of easily smelted rich ore in a charcoal fire either in the open or in a small brick or stone shaft, using the force of the wind to raise the temperature of the fire. By doing this the charcoal (which is carbon) combines with the oxygen of the ore to form carbon monoxide gas leaving the iron behind, which melts and trickles out at the bottom. The use of carbon in this fashion to reduce (as the chemist calls it) the ore, is the essential basis of iron smelting to this day.

Later on the bellows were invented which made the ironmaster independent of the weather and also enabled him to concentrate the wind or blast in a tube and put it exactly where he needed it. To this day it is possible to find some primitive native tribes in Uganda who still smelt iron in a tiny little shaft, using hand bellows to raise the wind.

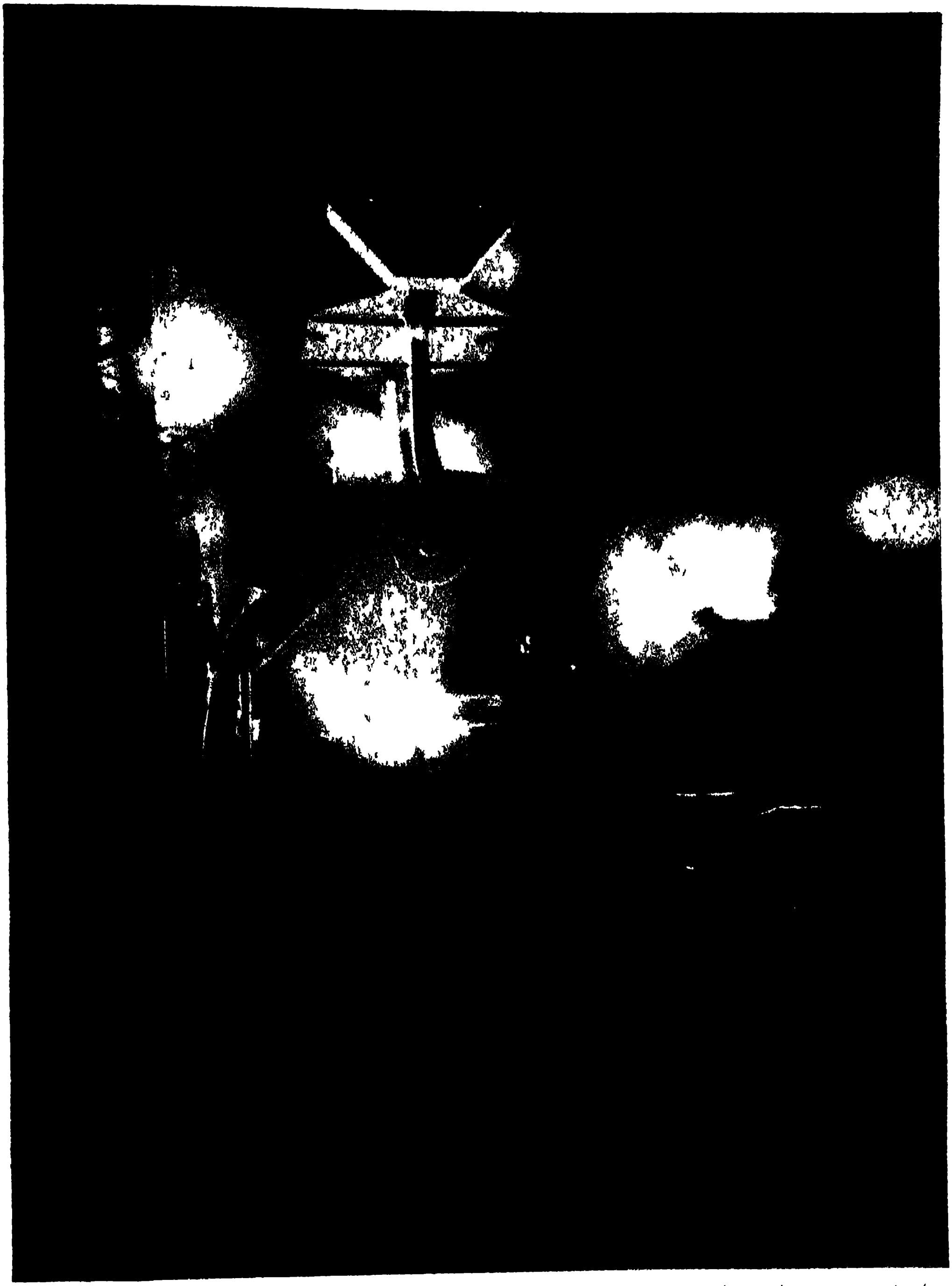
Iron produced in this fashion is not like the iron the modern blast furnace makes because being smelted at a comparatively low temperature it did not take up much carbon from the charcoal and thus could be forged with the hand hammer and welded together almost as soon as it had been produced. In this fashion the iron which was forged into the wonderful

Finally, there is the carbonate ore, *siderite*, named after the Greek word for iron. In its pure state it contains 48 parts of iron per 100. Large deposits of siderite of varying purity are worked in the English Midlands, the field stretching from North Lincolnshire, down through Northamptonshire and west to North Oxfordshire. It is also mined in the Cleveland Hills of North Yorkshire. It is now our most important British source of iron, and while the ores found here are not very rich they often contain lime which makes them more easily smelted.

Another common iron mineral is *pyrite* or *pyrites*, a compound of iron and sulphur. This, however, is not used as a source of iron since the sulphur makes it almost worthless for this purpose. Large quantities are mined, though, to extract the sulphur for the manufacture of sulphuric acid. It occurs as an impurity in some coals, where you may detect it as a brassy crystalline deposit on the surface.

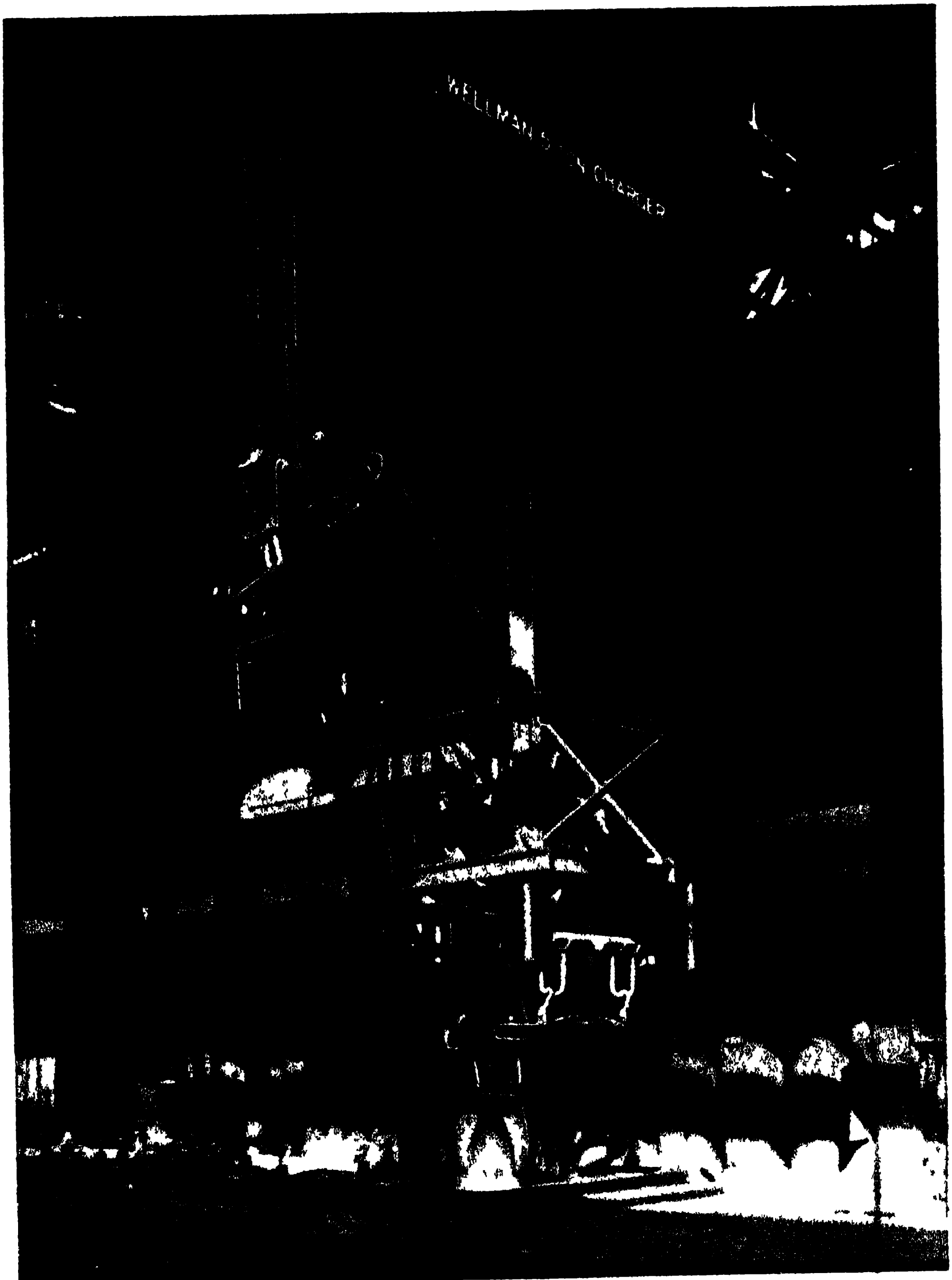
The Discovery of Iron Smelting

How exactly men came to discover that iron ore could be smelted and would yield a metal we do not know.



CASTING STEEL INTO INGOTS

Here we give a scene in a big steel works after the molten steel has been brought from the furnace in one of the big ladles (seen above) to the casting bay. The ladle is suspended from the overhead crane while the ingot moulds are filled with molten metal. The moulds are placed on stout steel bogies and these are then taken at once to the stripping bay. It is during this operation of teeming the molten steel into the moulds that the final and most important sample of the steel is taken for analysis.

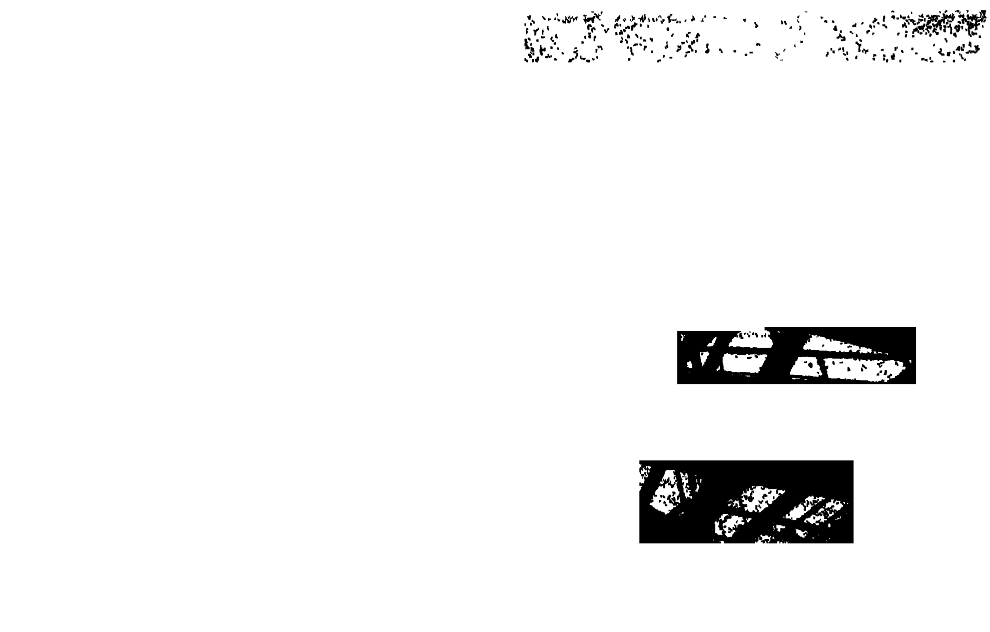


The Wellman Smith Owen Engineering Corp'n Ltd

AN INGOT CHARGING MACHINE AT WORK

The ingots of steel have been stripped, that is removed from the moulds as soon as they are sufficiently solid. They are now picked up by the ingot charging machine and placed in a furnace called a soaking pit, the purpose of "soaking" being to bring the whole ingot to an even temperature all the way through. At this bright red heat the ingot is ready to proceed on its way to the first stage of hot rolling in the cogging mill.

KEEPING THE FURNACE FILLED



The furnace shaft is kept filled with solid material up to the top and once a furnace is blown-in it goes on making iron night and day for a period of years. Here we see the "skip-track" running up to the top of the furnace. A skip loaded with iron ore and coke is on its way up.

Photos: B.I.S.F.

Modern furnaces are charged mechanically and there is very little hand labour attached to them. As illustrated here, however, a watch is kept on what happens. The blast furnace "keeper" is seen taking a look inside through the blue glass let into the tuyere.

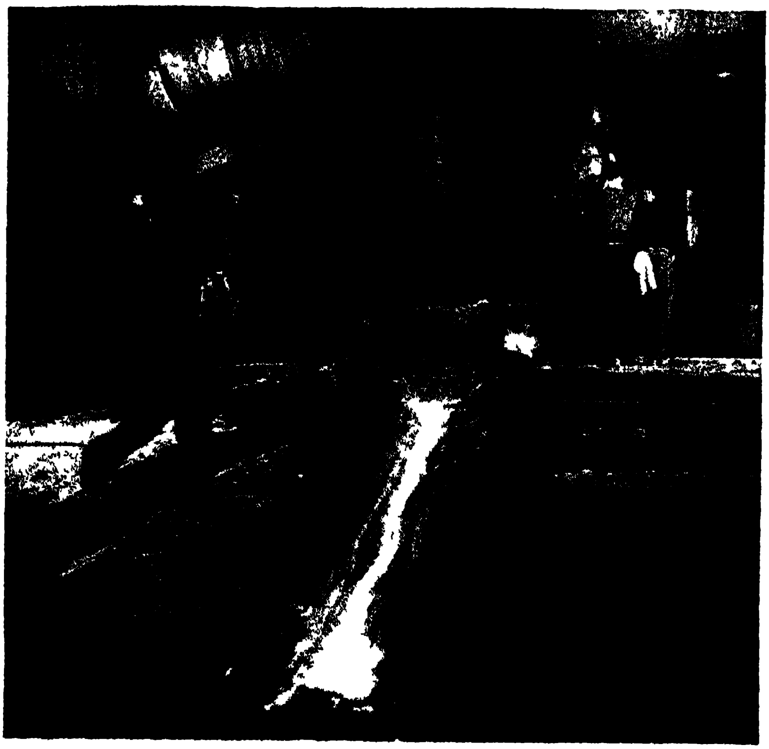
steel sword-blades made at Toledo and Damascus must have been produced, and the remarkable pillar of almost pure iron at Delhi in India. To-day, we have lost these arts, but we produce our iron on a gigantic scale in comparison.

Modern Blast Furnaces

As the years passed so the furnaces and bellows used grew larger and iron containing carbon and, therefore, not immediately forgeable, was produced. By the fourteenth century iron made from the blast furnace was used for the most part for making cannons and similar items and was *cast* into moulds directly it was tapped from the furnace. Charcoal was still used as a fuel and from this time to the end of the seventeenth century the Weald of Sussex was the great iron-smelting and cannon-founding district of England. Siderite or *clay ironstone* was quarried locally and the forest systematically felled to make the charcoal.

In 1709 Abraham Darby of Coalbrookdale, Shropshire, first succeeded in smelting iron, using not charcoal, but *coke*, and from this point the development of our modern blast furnaces really begins. Coke is stronger and more porous than charcoal and the height of the furnaces, which formerly was only about 35 feet at the maximum could now be raised according to the strength of the bellows. With the coming of the steam engine these, of course, also became larger and more powerful.

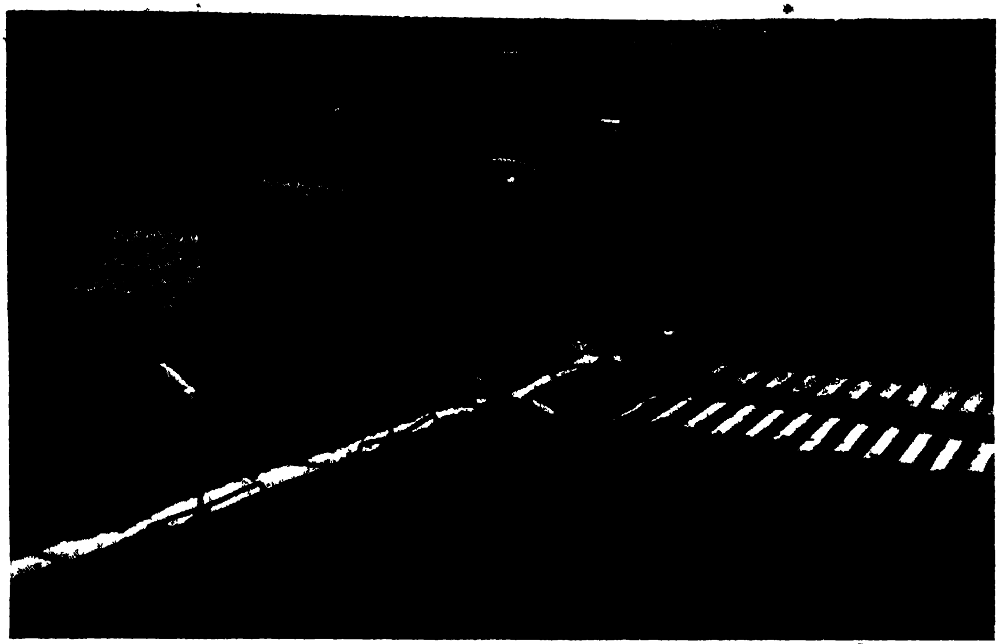
The modern blast furnace is a circular tower about 100 feet high and up to 27 feet in diameter across the bottom. The shape of the interior you see illustrated on page 43. Air is blown in through a series of nozzles known as *tuyeres* set around the hearth and the ore, coke and limestone enter at the top through an arrangement of two hanging cones or bells fitting into steel rings which are gas tight. One bell opens while the other is shut which ensures that as batches of solid material are put into the furnace no gas leaks out, and



Steel Company of Wales

TAPPING BRITAIN'S LARGEST BLAST FURNACE

Pig iron derives its name from the way it always used to be cast into shallow troughs arranged about a central "runner," rather like baby pigs against the mother sow. Various other methods are also used nowadays. Here we see the 25-foot blast furnace at Margam being tapped



Sport and General

RUNNING INTO THE MOULDS

We have seen the molten pig iron being run from the furnace and in this photograph the molten metal is being run into shallow moulds or troughs in a gently sloping bed of sand. Here it is allowed to cool and become the solid pig iron.

all the furnace gas is led away by the big offtakes or pipes from the top.

The top of the furnace is quite cool, the hearth is at a white heat and little discs of blue glass are set into the tuyeres to enable the man in charge to keep an eye on the interior. As the smelting proceeds so the molten iron collects in the hearth, and floating on top is the slag, that is, impurities which have combined with the limestone to form a molten mass which is easily removed. Iron and slag are run out at intervals through the slag-notch and taphole provided.

The furnace shaft is kept filled with solid material up to the top and once a furnace is "blown-in" it goes on making iron night and day for a period of years, only stopping when the lining, which is made of heat-resisting substance called firebrick, is worn out and has to be renewed. Modern furnaces are charged mechanically, there being very little hand labour attached to them.

Modern blast furnaces are nearly all provided with hot blast, after the invention of James Neilson, a gas engineer of Glasgow in 1828. The method of providing this is illustrated on page 4. Some of the issuing furnace gas after cleaning is burned in a Cowper stove and heats up a column of firebricks to a bright red. After some hours the incoming cold air blast is diverted through this stove to pick this heat up while the furnace gas is burned in another stove, which was formerly heating the blast. Every blast furnace must have at least three stoves attached to it, two working to heat the blast and one standing spare, since the brickwork in a stove has to be repaired and cleaned every so often. The use of hot blast saves a great deal of coke.

The remainder of the furnace gas is used to raise steam to work the blowing engine or generate electricity and other jobs.

The smelting of iron ore in the blast furnace is the first stage in the

production of all our items of iron and steel, and the material which issues from the blast furnace taphole is called *pig iron.*

Blast furnaces in Great Britain now produce about 9½ million tons of pig iron every year. About 7½ million tons of this are used to make *steel*, the remaining 2 million tons make *cast iron* and a very much smaller quantity of *wrought iron.*

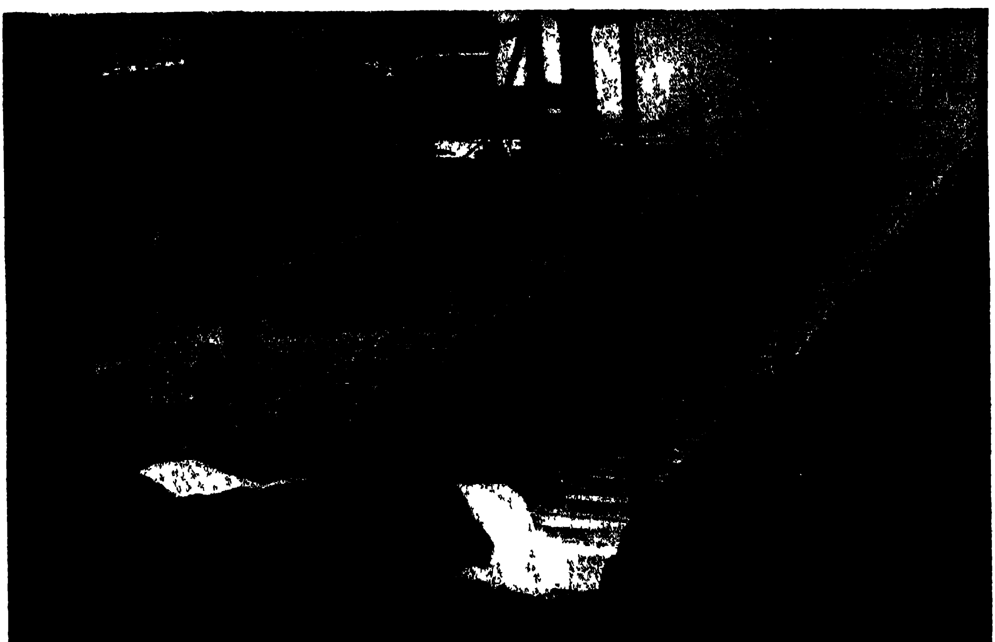
What Happens to Pig Iron

We saw from the "family tree" on page 41 that pig iron is an intermediate product, and from it cast iron, wrought iron and steel are manufactured. Pig iron derives its name from the way it always used to be cast into shallow troughs in a gently sloping bed of sand, these moulds being arranged about a central "runner" rather like baby pigs against the mother sow.

In a number of ironworks this is still regularly done and the resulting iron when cooled and solid is pulled out of the sand beds with chains attached to an overhead crane, the "pigs" being broken away from the "sow" by a blow from a sledge hammer. Since pig iron contains about 8 parts of impurity in every 100 it is brittle and breaks easily. This material is then known as "sand cast pig."

Many furnaces now, however, cast their iron into a casting machine which is essentially a long endless chain on which are supported a series of small iron moulds called "pallets." These move slowly along and the stream of metal fills each one as it passes. Further on they are sprayed with water, and by the time they reach the other end of the chain the iron is solid and may be tipped straight out into a waiting railway wagon. All the labour of preparing the sand beds, filling them, and then breaking up the solid iron is avoided. The "pigs" of iron (as they are still called) are also much cleaner.

In some cases, where the pig iron from

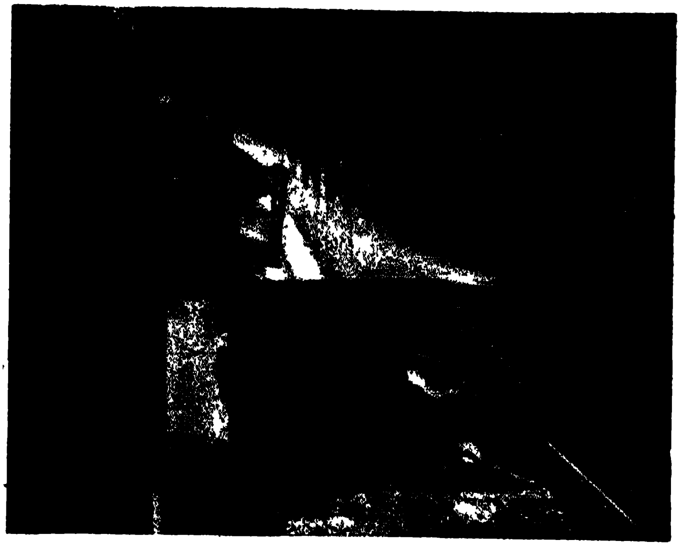


B I S F.

RUNNING INTO THE CASTING MACHINE

Instead of running the molten metal into the shallow moulds as seen on the previous page, many furnaces now run the molten pig iron into a casting machine Further up the line the pallets are being sprayed with water, and the clouds of steam can be seen in the background.

the blast furnace is to be used for making steel, and the steelworks is reasonably near at hand, the iron is never cast at all, but is poured into large holding vessels lined with fire-brick and mounted on railway wheels called "hot metal ladles." The "hot metal," as it is then called, is hauled to the steelmaking furnaces while still molten and all the heat contained in it is thus saved. We shall see more of this when we look at steel being made.



B.I.S.F.

FILLING A LADLE

Here is molten pig iron pouring into a hot metal ladle. When full the ladle will be hauled along the railway to the steel works and the iron charged to open hearths or converters.

Making Things of Cast Iron

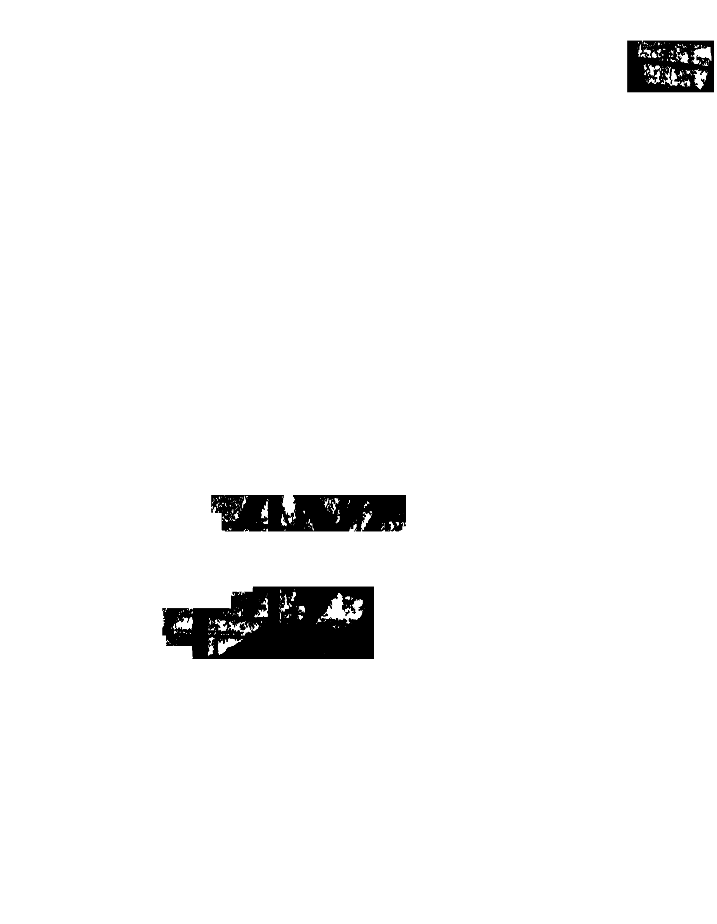
It is possible to cast pig iron straight into a mould as soon as it leaves the blast furnace, like the old Sussex cannon founders, in which case it becomes cast iron at once. This is still done occasionally, but it is not common, firstly because it is not often convenient to have to make up intricate sand moulds near a blast furnace and secondly because the iron from a blast furnace is not always of a suitable composition to make good castings.

Pig iron destined to become cast iron is usually re-melted in a kind of miniature blast furnace called a *cupola.* This is simply a shaft lined with firebrick with a number of rectangular tuyères let in near the bottom, a ·ft cold blast being provided by a fan blower. Coke and solid pig iron are fed in about three-quarters of the way up and molten iron tapped out at the bottom. As a rule no effort is made to reclaim the heat in the gases, which burn off at the top. About 4 cwts. of coke are required to melt a ton of iron. By adjusting the kinds of pig iron and scrap charged, the chemical composition of the resulting molten iron can be controlled within certain limits. The "nature" of cast iron is chiefly determined by the quantities of silicon and phosphorus it contains. Iron from the cupola is cast at about 1 200° C. temperature, a bright yellow-red heat.

Moulding and Founding

Making cast iron objects in sand moulds is called iron founding and the place where it is done an iron foundry. Iron foundries are to be found all over the country, ranging from small ones where castings only a few pounds in weight are made, to much larger ones where the castings may weigh as much as 20–30 tons and sometimes even over 100 tons.

First comes the operation of pattern making, a highly skilled job, where a replica of the object to be cast is made up in wood and varnished to protect it from the effects of damp. To allow for the iron shrinking as it cools, the pattern must always be made a little larger than the final casting.



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A LADLE CRANE IN ACTION

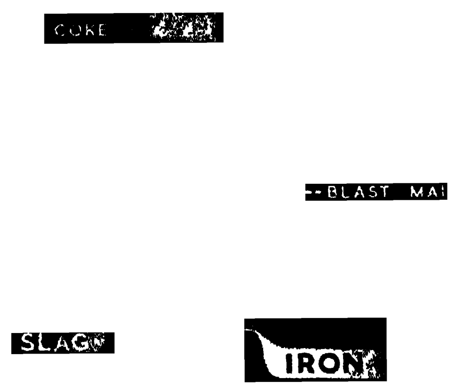
We have seen the molten iron being poured into a hot metal ladle The iron has now travelled to the steelworks and is poured into a big holding vessel called a "mixer." From here it will be taken out as required

The pattern is then placed inside a stout iron frame called a moulding box and special heat-resisting sand, very slightly moistened, is shovelled and rammed around the lower half of the pattern until it forms a solid mass. This makes the "drag" half of the mould. A sprinkling of fine dry parting sand is put over the surface of the moulding sand, then another moulding box is put on and more moulding sand rammed in to make up the "cope" half. The two sections of the mould are then parted, the pattern is withdrawn, and the two halves allowed to dry. Shortly before the metal is due to be poured the two halves are put together again and holes are cut in the cope to allow the molten metal to flow in. After the metal has been poured in, the mould is left standing for a certain length of time to allow the iron to solidify sufficiently. Then the mould is "shaken out" by hammering the sides of the box or by placing the whole thing on a vibrating grating. The sand breaks up and the crude red-hot casting is revealed.

After cooling the casting must be cleaned up or "fettled" to remove any sand sticking to it and cut off any unwanted bits such as the "gates" where the iron flowed in. If it is a complicated casting it is sometimes placed in a furnace at a dull red heat to relieve any tensions which may have been caused during uneven cooling down.

There are, of course, many variations on what has been described above. For instance, the cope and drag may be moulded separately on separate patterns. Where a casting is to be hollow inside a specially moulded piece of sand called a "core" must be inserted into the mould. For certain forms of long cylindrical castings (*e.g.*, water mains, sewer pipes and the like), the mould is spun around during

pouring making a "centrifugal" casting. The entire subject of moulding and casting needs a whole book to describe properly. It is not, of course, confined to iron either, casting objects in copper, brass, bronze, zinc alloys, light alloys, etc, is very widely practised and has been so for a long time. A single pattern can be used to make a great many moulds, and casting iron as described above is very well suited to the making of a large number of the same item, or mass production as it is called Foundries engaged on the mass production of small parts are often fully mechanised, the moulding being done by machines, the moulds when completed being placed on roller tables where a light push enables them to be



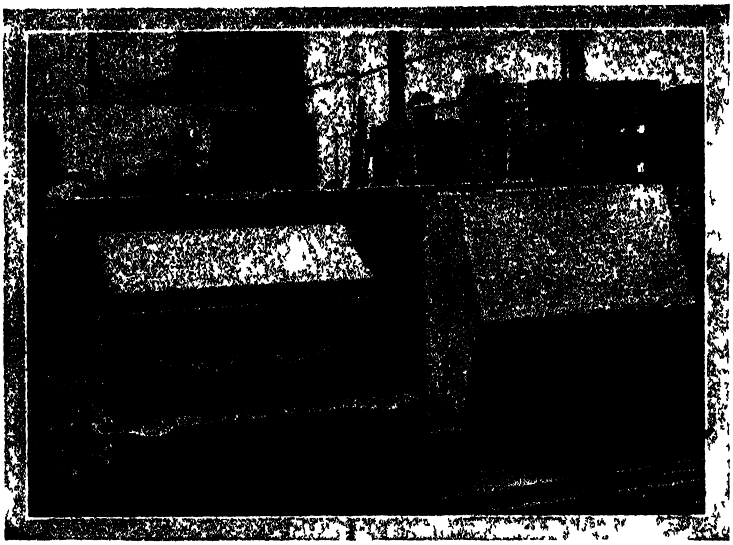
CUPOLA FURNACE

This diagram illustrates the cupola furnace used in making cast iron The pig iron is re melted with a certain quantity of scrap By altering the quantity of scrap and using various sorts of iron the founder can control the quality of the cast iron within certain limits

B I S F

FOR MAKING CAST IRON

Pig iron which is to be made into cast iron is usually remelted in a kind of miniature blast furnace called a cupola Here we see the iron being tapped from a cupola in a small iron foundry near London.



MODELS IN WOOD

The two curious objects seen here are wooden patterns for making moulds in which metal will be cast To allow for the shrinking of the metal as it cools, and for any machining of the surface, they are slightly longer every way than the finished casting is to be

run from one end of the shop to the other The sand is as far as possible handled by conveyor belts.

This is, of course, impossible with large mouldings which are made up on the shop floor, while very large ones have to be made up in a pit to enable the men to get at them properly.

Common cast iron objects are fuse-boxes, lamp standards, drainpipes, house radiators, gutters, gas-stoves, kitchen ranges, etc. In a motor car the cast iron cylinder block is most important. Cast iron is not particularly strong, or tough, but it is cheap, and is therefore used where something hard, solid and weighty is wanted, but where it will not be subjected to shocks which might make it crack Unlike steel and wrought iron, cracked cast iron is not easy to repair satisfactorily.

Cast iron is an unspectacular "maid of all work," but we should be a lot worse off without it.

Photos Foundry Trades Journal

A COMPLICATED MOULD

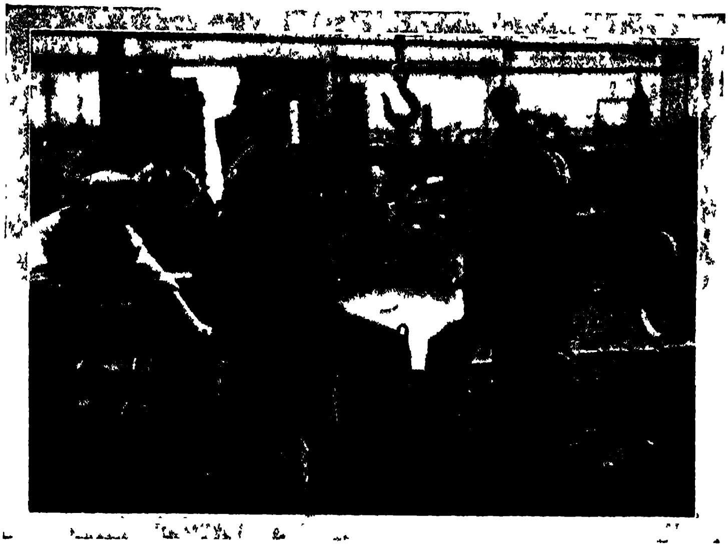
This shows the "drag" portion of a large and complicated moulding Before the molten metal is poured in the "cope" will be placed over the top

Making Wrought Iron

Wrought iron is now something of a rarity, since it has so largely been replaced by steel, but we should not ignore it entirely for a certain amount is still made and will continue to be made.

As we have seen, the pig iron which comes out of the blast furnace is

brittle, and cannot be shaped under the blacksmith's hammer because it contains up to 8 parts in 100 of other elements or impurities, chiefly carbon and silicon which make it unweldable, and phosphorus and sulphur which make it brittle.

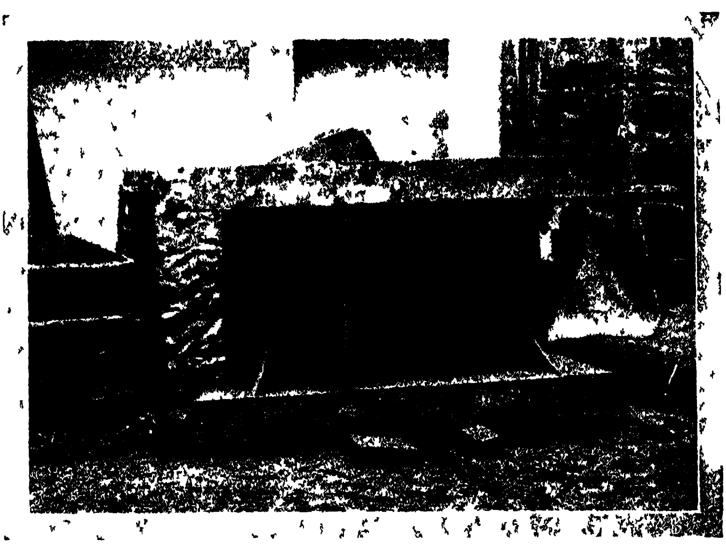


CASTING IN PROGRESS

The white hot metal has been brought in the ladle held between side-shafts supported by a crane It is now being poured into the mould where it will be left for a certain length of time to allow the iron to solidify

In 1784 Henry Cort invented a process called "puddling" which converted pig iron into an iron which could be forged, because, in puddling, the carbon, silicon, phosphorus and sulphur were removed, leaving an almost pure iron behind.

A puddling furnace is illustrated on page 54. It is what is known as a reverberatory furnace, because the iron is heated by the flames above it, heat being reflected downwards from the roof. During puddling the iron pigs are placed on the hearth of the furnace and the heat of the flames is enough to bring them to a pasty, half molten condition. Men then push and poke the mass about with iron rods and the oxygen in the hot air inside the furnace combines with the carbon to form carbon monoxide gas and with the other impurities to form a pasty slag. When the puddler considers that the iron is ready he gathers it up into a ball, pulls it out of the furnace and places it under a steam hammer By the blows of the hammer the slag is



Photos Foundry Trades Journal

TO BE SMOOTHED BY MACHINE

In this photograph the casting is seen after shaking out It must now be cleaned up or "fettled" and then smoothed to the exact shape.

British Iron and Steel Federation

IN THE WORKS' LABORATORY

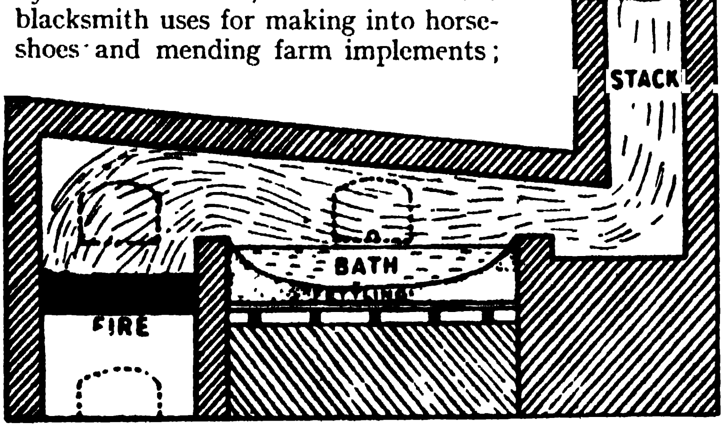
Here we see a corner of the chemical laboratory of a big iron and steel works. In here all the samples of steel taken during and after melting will be chemically analysed to make sure that they are within the specification.

squeezed out of the mass and the iron beaten out into a rod or strip.

Wrought iron has two very valuable properties, it can be welded at a red heat under the blacksmith's hammer and it is remarkably resistant to rusting. It is soft but tough, and does not crack. It is nowadays used for making certain kinds of chain, each link being welded round the last one by the blacksmith; for bars which the blacksmith uses for making into horseshoes and mending farm implements; and finally for ornamental "filigree" ironwork.

Between its invention in 1784 and the invention in 1856 of a method of producing steel on a large scale, wrought iron was of tremendous importance. The first railways, for instance, were all laid with wrought iron rails and the first locomotives and steamships were largely built of this material.

We still speak of the "iron road" and the "iron horse" although they have both long since become steel. Steel can be made very much stronger than wrought iron, and it was the advent of steel which opened the way to the development of the railway's great competitors—the motor car and the motor lorry.



THE PUDDLING FURNACE

The process known as "puddling" was invented by Henry Cort in 1784. During the puddling the carbon, silicon and phosphorus are removed, leaving behind an almost pure iron.

THE STORY OF STEEL

Steel Company of Wales

AT BRITAIN'S LARGEST STEELWORKS

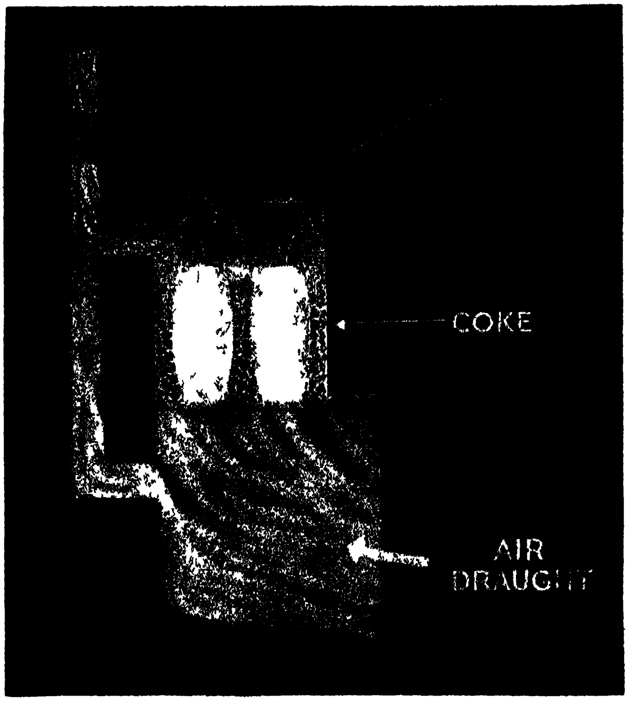
This photograph was taken during the final stages in the erection of the Abbey Works at Margam in South Wales On the left are seen Nos 1 and 2 Blast Furnaces, while in the centre are the Hot Blast Stoves.

WE now come to look at steel and how it is made, and to understand this properly we must first be quite clear what steel is and how it differs from cast iron and wrought iron.

Cast iron, as we saw, is nothing much more than re-melted pig iron cast into sand moulds. It is not refined in any way and therefore all the impurities in pig iron find their way into cast iron in much the same quantities.

Wrought iron is pig iron which has been given a strong " dose " of refining in a puddling furnace and almost all traces of the four impurities have been removed. The iron, however, is never made completely molten, only pasty, and the refining has to continue until the puddler considers that it is all done. He cannot exercise any close control over the progress of refining, or stop it any time he wishes.

Steel, however, differs from cast iron and wrought iron in two important aspects. Firstly, it is refined in the fully molten condition, and secondly we can exercise a very close control of the exact quantities of carbon, silicon, phosphorus and sulphur it finally contains. The most important of these is carbon, which is contained in steel in quantities varying from 1 in 100 to 1 in 1,000 and largely determines its hardness and toughness. In the last fifty years we have also learned how to add " alloy " elements, manganese, chromium, nickel, molybdenum, tungsten and several others to steel and so increase its range of properties enormously, and we are still learning to make more and different steels every year. Steel is now quite the



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MAKING CRUCIBLE STEEL

This diagram shows the principle of the Crucible Process. The clay pots are immersed in a coke fire which heats them to 1,600° C. and melts the steel.

most versatile structural material we possess.

The Crucible Process

Before the first proper " steel " was made, the nearest approach to it was " cemented iron." This was made from Swedish iron bar (a pure iron made in Sweden from magnetite ore smelted in a charcoal furnace) which was packed in air-tight boxes full of charcoal and then kept at a red heat for a period of weeks in a " cementation " furnace. In this way a certain amount of carbon could be made to re-enter the iron, which increased its hardness. The chief trouble with cemented iron, however, was the fact that the carbon did not always enter the iron evenly, and this non-uniformity often made it unreliable stuff to work with.

In 1740 a clockmaker of Doncaster named Benjamin Huntsman had grown tired of repeated failures in his clock springs of cemented iron and he determined to do better. He rightly considered that the cause of the trouble was the uneven distribution of the carbon and he decided that the only safe way to ensure an even distribution was to get the iron fully molten so that the carbon it contained could " diffuse " easily throughout the whole mass. After many unsuccessful attempts Benjamin Huntsman finally achieved this, and founded a steelworks in Sheffield which still bears his name. His process is called the " Crucible " process and the metal produced is " Crucible Steel."

Huntsman's process is essentially simple and is illustrated on this page. It is simply a clay pot (the crucible) embedded in a coke fire in which the steel is melted in much the same way as you might melt wax in an earthenware dish. The point is, though, that to get steel fully molten we have got to go to a temperature of nearly 1,600° C., a really *white* heat, and Huntsman's real problems were first to make a clay pot to withstand this and then to design a fire which would heat the pot evenly from top to bottom. (It should be noted that cast iron is fully molten at only 1,200° C. because its impurities lower its melting point. When these are removed the melting point is much higher.)

The great centre of cutlery manufacture—Sheffield—was built up on the crucible process of steelmaking. Three things all helped in this—deposits of a clay called " ganister " to make the pots, deposits of coal for the fires, and water power from the River Don to work the hammers and forge the knives.

Although we now have much less crude methods of making steel, the crucible process is still very much alive, though not, of course, anything like as extensively as it was. It is well suited for making small quantities of high-quality steel, but is not a " tonnage " process. Since the pot and its load of molten steel have to be man-handled out of the furnace and poured by hand, each batch of steel made cannot be more than about 80 pounds in weight at the maximum.

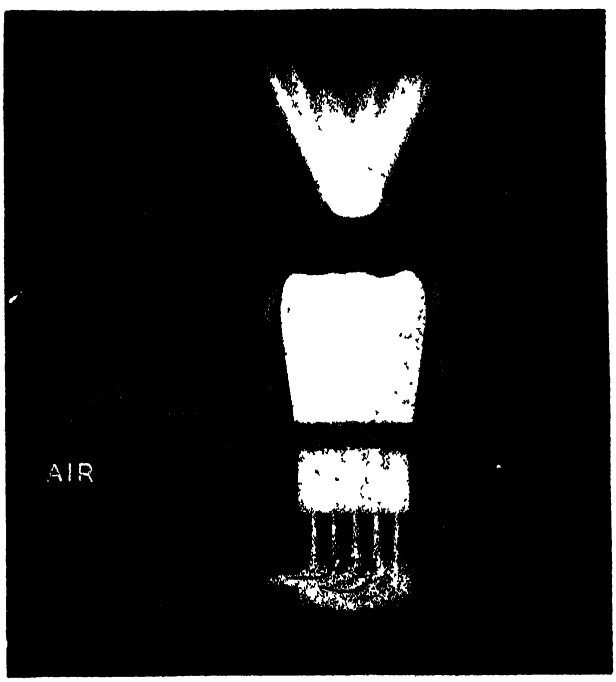
Making steel by the ton and more came just over a 100 years later, in 1856.

Invention of the Bessemer Process

Modern steelmaking may be said to have begun in the year 1856, when Sir Henry Bessemer showed the world how to make steel from pig iron in one stage and in large quantities.

Bessemer was the son of a type-founder and was a man of proved inventive ability even before he took out the patent which made his name famous. One day he noticed that some pieces of pig iron which had been left inside a special furnace of his own design were in fact altered to pure, and therefore malleable, iron, the carbon and silicon seemed to have been " burned-out " by the furnace blast. This gave him the idea that perhaps he could do the same thing in a more controlled fashion. His first test was performed on a batch of Swedish pig iron which he melted in a Huntsman crucible and then inserted a tube and blew air through it. The idea succeeded and to his surprise the air did not cool the molten pig iron, as one might have expected, it actually warmed it up due to the heat of the chemical reaction between the oxygen and the " burned-out " carbon and silicon. Bessemer immediately realised the importance of this, namely, that provided he could blow fast enough he ought to be able to make malleable iron from molten pig iron without using any other fuel. Accordingly he arranged for a much larger vessel to be filled with molten Swedish pig iron and blew air through a series of holes in the bottom. Sure enough, when the flame of the burning carbon had died down the impurities had been removed and the metal was hot enough to be run out into moulds. The new process was born.

However Bessemer's troubles were not altogether over. For one thing the new process would not remove sulphur and phosphorus from the metal, and a large-scale experiment in South Wales proved a costly failure before this was



B.I.S.F.

A BESSEMER CONVERTER

Here we see the principle on which the Bessemer converter works. The blast enters the wind box through a hollow trunnion, so the blast may be turned on with the converter in any position.

POURING IN THE METAL

Molten pig iron is here being poured into a Bessemer converter. The converter lies horizontally while this is being done and the metal does not run down the tuyères. By the Bessemer method steel is made from pig iron in one stage.

realised. Only Swedish pig iron or pig iron made from Cumberland iron ore could be used. Then again the nozzles or "tuyères" of the converter vessel did not last long and little commercial progress was made until a Swede named Goransson advised raising the blast pressure and making narrower tuyères. The worst trouble was, however, that "blown" metal which had had the carbon taken out of it in this way was full

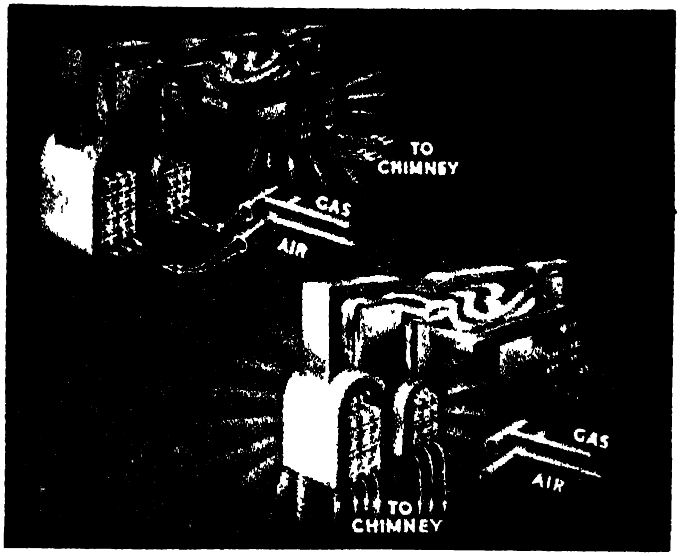
Photos: British Iron & Steel Federation

THE CARBON FLAME FROM THE CONVERTER

In this photograph the Bessemer converter has been swung rapidly to the upright position after filling. Immediately the action starts and the "blower" judges how far it has gone from the appearance of the converter flame, that is from the burning carbon monoxide issuing from the converter mouth as seen here.

of oxygen, and when it cooled down in the mould large volumes of gas were evolved. The metal, in fact, behaved very like ginger beer on a hot day, it climbed out of the mould just like "gassy" liquid climbing out of the bottle, leaving only about half of itself behind.

This problem was solved by David Mushet. He showed that if manganese was added to the iron, after blowing it would neutralise the effect of the oxygen and the metal could then be cast quite comfortably. Manganese is added to Bessemer metal in the form of ferro-manganese and spiegeleisen, both of which also contain carbon so that the final carbon content of the metal can be accurately adjusted at the same time, and thus the pure malleable iron becomes what we can properly call *steel*.



B.I S F

THE OPEN HEARTH FURNACE

This drawing shows the general principles of the Open Hearth furnace One of its advantages over the Bessemer converter is that it can melt and refine scrap It is also a slower process and can therefore be more precisely controlled

The Modern Bessemer Process

Early in his experiments Bessemer realised the advantage of conducting the "blow" in a vessel mounted upon pivots called "trunnions," so that it could be filled or emptied without having to keep the blast on to prevent the steel running down the tuyères. He designed a pear-shaped converter, and the shape of this vessel has not greatly altered to this day. Modern converters usually hold about 25 tons of molten pig iron and complete the conversion of this to steel in about fifteen minutes. The hot metal which has come from the blast furnace in a hot metal ladle is poured in while the converter is lying horizontal and then the blast is turned on and the converter swung rapidly to the upright position. Immediately the action starts and the "blower" judges how far it has gone from the appearance of the converter flame, that is from the burning carbon monoxide issuing from the converter mouth.

In the early stages the flame is weak but accompanied by a large number of bright sparks. This shows that the silicon is being oxidised. After about five minutes these die away and the flame brightens up and becomes longer. The carbon is now coming out, and this continues for about ten minutes. Small drops of white hot-slag fly out making a brilliant display. Towards the end of the reaction the flame shortens and the blower, watching it carefully, turns down the wind and brings the converter down to the horizontal position. First the slag is poured off and then the ferro-manganese and spiegeleisen are shovelled in. After a few moments to allow this to be absorbed the big steel ladle is brought

underneath and the contents are poured into it.

The entire operation of turning 25 tons of iron into steel will have taken less than twenty minutes and the temperature of the metal will have been raised during conversion from about 1,300° C. to 1,600° C. The inside of the converter will be white hot, and in order to lose none of this valuable heat the converter is immediately refilled and another blow starts. The converter will work day and night like this until it has to stop to have a fresh bottom fitted, after about fifty blows, or to be entirely re-lined, after about 200 blows. Thus Bessemer steelworks have some three to five converters installed, so that when any one of them has to be re-bottomed or relined the others can maintain production.

Getting Rid of Phosphorus

Bessemer's original process used a converter lined with silica, technically known as an acid lining, and he could not remove sulphur and phosphorus from pig iron. This rather serious drawback was overcome in 1875 by Sydney Gilchrist Thomas who was a Magistrates' Clerk by profession and who studied chemistry as a hobby. He suggested using a basic lining of a material called dolomite and then adding lime to make a basic slag. Unlike the silica lining the dolomite living could withstand the chemical action of the basic slag. With his cousin Gilchrist, who operated a steelworks at Blaenavon in South Wales this process was perfected and the Basic Bessemer or Thomas process is now extremely important, particularly in France, Belgium and Germany where the iron ores nearly all contain a considerable amount of phosphorus. Not only does the process remove this phosphorus but the basic slag which carries the phosphorus away is a

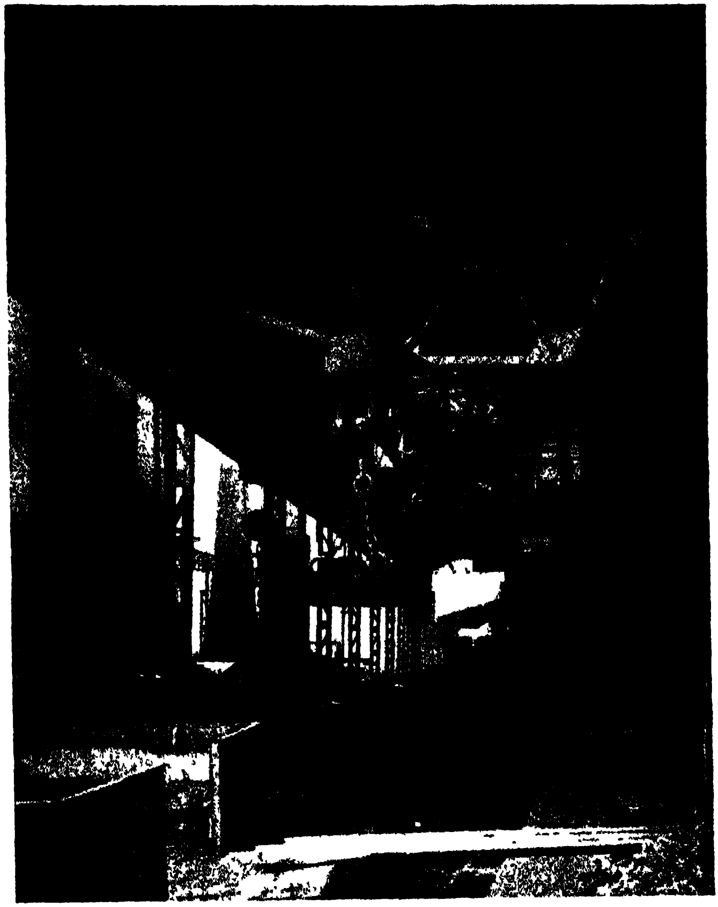
B.I.S.F.

IN FRONT OF A TILTING OPEN HEARTH FURNACE

This picture of men at work in a large steelworks shows the front of a big tilting Open Hearth furnace which is being "fettled" after tapping. The regenerators which heat the air and gas are underneath the platform on which the men are working.

valuable fertiliser and a source of considerable profit to the steel-maker.

In Great Britain, however, there are now only three large converter steelworks which between them produce about 1 million tons of steel every year. Converters have been replaced by Open Hearth Furnaces.



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UNDERHUNG JIB CRANE WITH LIFTING MAGNETS

Cranes with electro-magnets are used to lift the scrap out of railway wagons and then put it into the boxes used for charging the Open Hearth furnaces. The operator on the travelling platform controls the crane.

The Open Hearth Furnace

The invention of the Open Hearth Furnace followed in 1864 very quickly after the Bessemer converter, for open hearth steel-making has two advantages over the converter. The first is that it can melt and refine *scrap* which the converter cannot, and the second is that being a slower process the analysis and temperature of the steel being made can be much more precisely controlled.

By 1860 the quantity of scrap becoming available was considerable. The Industrial Revolution and the coming of the Railway called for more and more ironwork and machinery, but no machine lasted for ever and in time had to be replaced by a new and more efficient one—and since there was no ready way of making use of the old iron, the scrap piles grew and scrap was very cheap. In addition the very act of making and using steel creates scrap. Just as when a tailor has completed cutting out a suit he is left with all sorts of odds and ends of cloth, so during casting, rolling, forging and building things of steel, odds and ends are left behind which all go to swell the volume of scrap.

Two men invented the open hearth furnace though they worked independently, Sir William Siemens in Britain and Martin in France, and the invention is generally known as the Siemens-Martin open-hearth furnace. Of the 15 million tons of steel produced every year in Great Britain, over 13 million tons are now made in the Open

B I S F

THE CHARGING MACHINE AT WORK

In modern steel works all the work of charging the Open Hearth furnace with pig iron and scrap is done mechanically. Here we see the charging machine as it swings round to face the open hearth. The door is raised and the box of scrap is pushed in and emptied.

Hearth. Some 7 million tons of scrap are melted.

The essential features of the open hearth furnace may be best understood by going back and looking at the old puddling process. Like the puddling furnace the open hearth is a reverberatory furnace, the charge is heated from the flames above it, the heat being reflected downwards by the roof. The temperature in the open hearth, however, has got to be some 400° C. to 500° C. higher than that used in puddling, since the steel is actually melted, not merely reduced to a pasty state. This is achieved by removing the coal fire from the furnace altogether and turning it into a gas producer, a blast of air and a jet of steam being blown up through a bed of glowing coal to make producer gas. This gas and the air to burn it are then conducted to the furnace through flues, but before they enter the hearth both are preheated to some 800° C. to 900° C by being passed through a checkerwork of red-hot firebricks very similar to the checkerwork in a Cowper Stove which heats the blast furnace wind. This hot air and hot gas then burn in the open hearth and make a flame hot enough to melt steel scrap.

The burnt gas leaving the open hearth is at a temperature of about 1,600° C. and it passes at once through a duplicate set of firebrick checkerwork, which it heats to about 900° C. Every fifteen to twenty minutes the furnace is reversed, *i.e.*, the air and gas change direction, just as the two Cowper Stoves on a blast furnace exchange their functions every few hours. This method of gas and air preheating is called Regeneration and the sets of firebrick checkerwork are known as Regenerators.

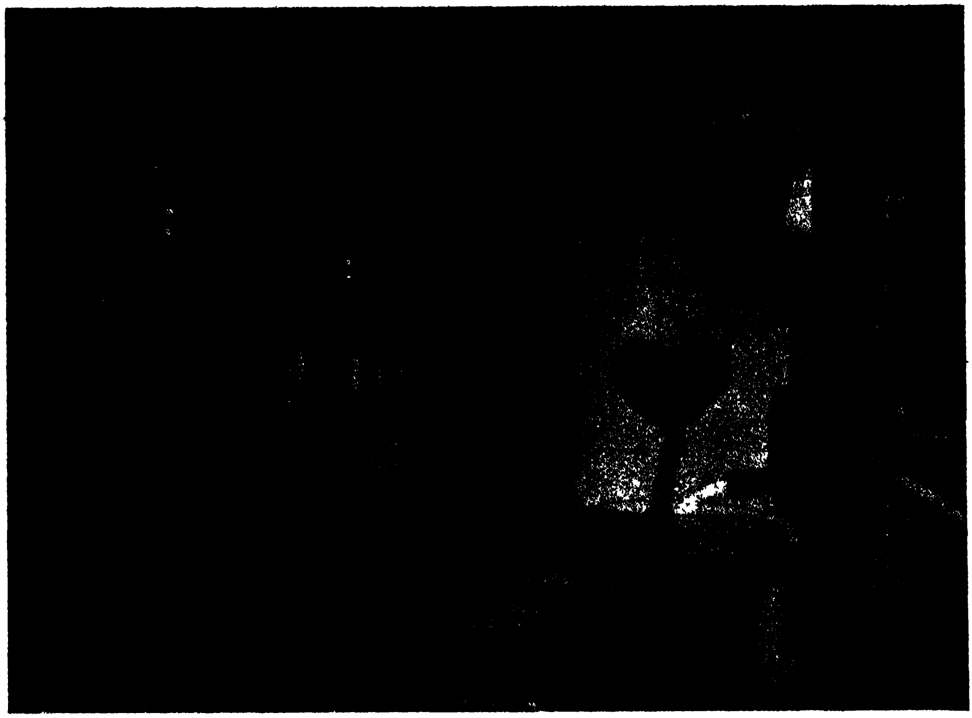
Many open hearth furnaces are now

STEEL IN THE MAKING

At the stage shown in this photograph the scrap is now partly melted and the hot metal goes into the open hearth The charging machine holds a special chute or launder and an overhead crane carries the ladle of metal and tilts it

Photos British Iron & Steel Federation

Nothing is left to chance in the modern steelworks and at every stage tests are made Here we see the temperature of the steel being measured by an immersion pyrometer to check the progress of refining During the " boil " small samples of the steel are taken and sent to the laboratory for analysis



B I S I

ANOTHER VIEW OF THE OPEN HEARTH FURNACE

In this photograph the view from the back of the Open Hearth furnace is seen during "tapping." On the right-hand side the molten steel can be seen as it pours over into the big steel ladle held ready for it by the overhead crane.

fired with oil squirted into the furnace in a fine spray. Only the air need then be preheated.

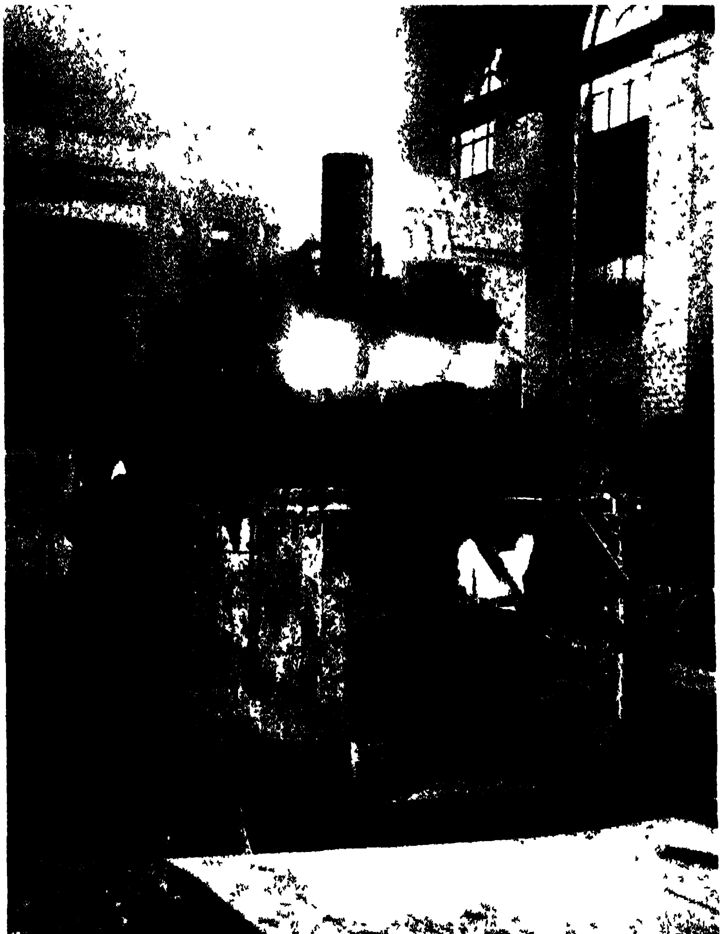
The hearth of the open hearth furnace is a rectangular shallow "bath" with gently sloping sides, 10 feet to 15 feet across, 30 feet to 50 feet long and 2 feet to 3 feet in depth. It is lined with heat-resisting material similar to that used in the converter, silica in the acid furnace, and dolomite in the basic furnace. The roof is usually made of silica. The charge is inserted into the hearth through lifting doors in the front wall and when fully molten and refined to exactly the chemical analysis desired, the steel is run out at the back, either through a taphole set in the bottom of the hearth, or, if the furnace is a large one the hearth portion is mounted on rockers and rollers, and can be tilted so that the molten steel flows out down a chute or launder. This is called "tapping."

Making Steel in the Open Hearth

In modern steelworks all the work of charging the open hearth furnace with pig iron and scrap is done mechanically. Scrap and solid pig are put into long rectangular boxes made of steel which are then picked up one by one by a charging machine, pushed into the furnace on the end of a long rod and turned upside down. The contents fall out and the box is then withdrawn for a fresh load. Some furnaces melt down the charge all from cold in which case they use about seven parts of scrap to three of pig iron, while the larger furnaces, and especially those made to tilt, will use molten pig iron, sometimes equal parts of hot metal and scrap or as much as three-quarters of

the entire charge may be molten pig. The hot metal will, of course, have been hauled from the blast furnace in a hot metal ladle, and is poured into the open hearth by the overhead crane.

To make a batch of steel in the open hearth, anything from 40 tons to 300 tons according to the size of the furnace, takes some ten hours to twelve hours. For the first five hours or so the charge is loaded into the hearth and in another three hours it should be fully molten. Most of the impurities except carbon have by then combined with limestone or sand put in with the charge to form a fluid slag on top of the steel. The rest of the time is devoted to getting the carbon out of the steel to exactly the desired final content. To do this the men shovel in some pure iron ore, usually hematite or magnetite. The oxygen in the ore then combines with the carbon in the steel and forces it out as carbon monoxide gas. Since this forms bubbles in the metal the steelmaker calls it the "boil." The furnace is burning gas or oil the whole time. This method of refining steel is the "upside-down" version of making pig iron. In the latter we used carbon to take the oxygen out of the ore in a rather rough and ready fashion, now we use the ore to take the carbon from the steel, but of course in a very precisely controlled operation.



Edgar Allen & Co Ltd.

A MODERN ELECTRIC ARC FURNACE

Another type of furnace which is used for the high quality alloy steels, such as stainless, or nickel-bearing, or silicon steels, is the electric arc furnace This photograph is of a 4-ton electric arc furnace at a Sheffield works.

During the "boil" small samples of the steel are taken out and sent to the chemical laboratory for analysis, and every so often the temperature of the steel will be measured with an "immersion pyrometer." In the old days the steelmaker merely relied on his judgment and the appearance of the steel to get the analysis and temperature right, now he has the aid of ingenious

instruments to make absolutely sure. Sometimes in order to speed up the refining of the steel, oxygen gas or compressed air is blown into the metal through steel tubes. This can often save quite a lot of time. When the carbon has been brought down to its final content the excess oxygen which has got into the steel is neutralised with additions of manganese and silicon, the taphole is opened or the hearth is tilted and the great mass of white-hot steel with slag on the top pours over into the ladle held ready for it. As soon as this is done the men inspect the inside of the furnace, patch up any holes in the lining with fresh silica or dolomite and spread a thin layer of fresh lining material all over the inside of the hearth ("fettling" as it is called), and within an hour the next charge is going in.

As long as the furnace is in a fit state the work of making steel goes on continuously day and night, the men working eight hour stretches or shifts. Every four months or so the furnace is cooled down and the roof and other worn-out brickwork is repaired.

The Electric Arc Furnace

Another furnace for making steel which is used for the high-quality alloy steels such as stainless (*i.e.*, rust-proof) steel containing chromium, nickel-bearing armour-plate steels and silicon steels used for making the interiors of dynamos, transformers and electric motors, is the electric arc furnace.

When two pieces of graphite (a form of carbon) are connected to a powerful source of electric current and momentarily touched together and drawn apart a kind of "bridge" is formed between them. This is called an arc and is intensely hot, the temperature reaching over 3,000° C. It is also very bright indeed and is sometimes used as a source of light. Arcs may also be struck between graphite and steel and between two pieces of steel. Sir William Siemens was the first to show that the electric arc could be used to melt steel.

The modern electric arc furnace is circular in shape with a hearth and a roof not dissimilar to the open hearth. The three graphite electrodes protrude down into the hearth through holes in the roof. The furnace is charged with steel scrap and then the electrodes are lowered until they touch the scrap and the arcs are struck. The heat melts the scrap which is then refined in very much the same way as steel in the open hearth, oxygen often being used.

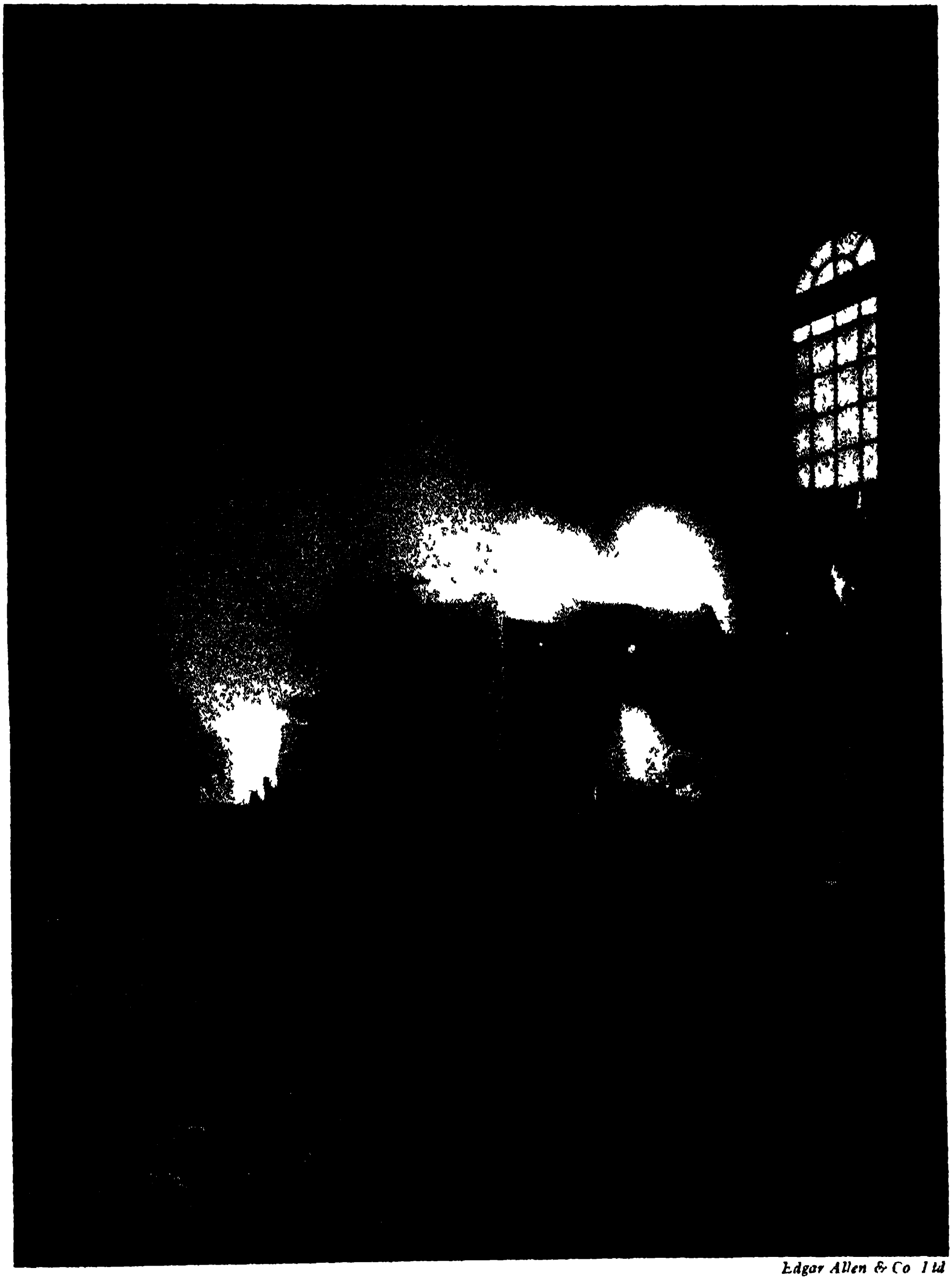
Electric arc furnaces vary in size from about 3 tons to 30 tons capacity. They are mounted on rockers and are tapped by tilting. The refining in the electric furnace can be even more closely controlled than in the open hearth, and the absence of the flames means that alloying elements such as chromium, silicon, molybdenum, etc., may be added to the steel without the loss which occurs in the open hearth.

The High Frequency Induction Furnace

Another application of electricity to steelmaking is the modern version of the crucible process—the high frequency induction furnace. This is the most recently invented steel-making furnace, being first put into commercial operation in 1922.

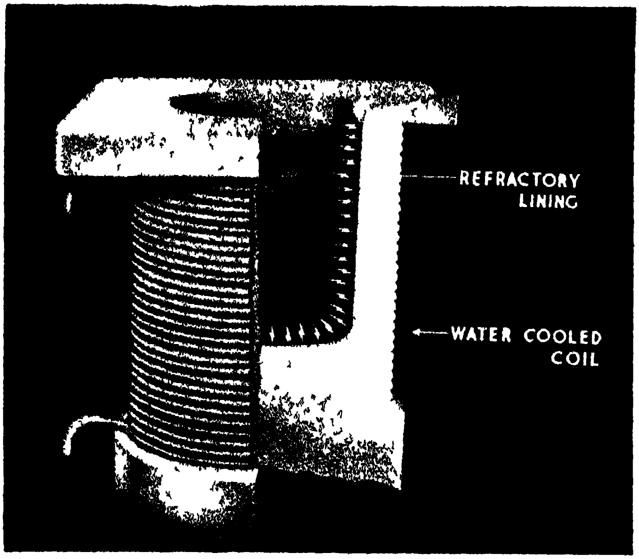
We have seen how steel can be made by melting it in a pot immersed in a hot coke fire, the heat passing through the walls of the pot from the fire to the steel. If, however, the pot is placed inside a copper coil which carries a high frequency alternating current, that is a current flowing backwards and forwards between 500 and 2,000 times every second, then heat sufficient to melt the steel will be generated actually in the metal itself. (The current for electric light "alternates" at fifty times a second.) The pot need now act only as a container and will not wear out anything like so quickly. The outside of the pot and

FOR HIGH QUALITY ALLOY STEELS



Edgar Allen & Co Ltd

Sir William Siemens was the first to show that the electric arc could be used to melt steel. These electric arc furnaces vary in size from about 3 to 30-tons capacity, and the refining in this type of furnace can be even more closely controlled than in the open hearth In this photograph oxygen is being blown into the steel in the electric arc furnace to remove the carbon. Great heat is developed in this process.



HIGH-FREQUENCY INDUCTION FURNACE

Another application of electricity to steel making is the high frequency induction furnace which is the modern version of the crucible process As seen here, the pot is placed inside a copper coil which carries the high-frequency alternating current

the copper coil may be cooled with water to give even longer life.

When this process was first publicly demonstrated in Great Britain the outside of the furnace used had a wooden casing. You can imagine the spectators amazement when they saw white-hot steel emerging from an unscathed wooden box!

This is the process which has very largely replaced the old-style crucible furnace for the manufacture of very high quality steels for the best cutlery and tools for instance Since the entire pot and coil may be mounted together and mechanically tilted, all the

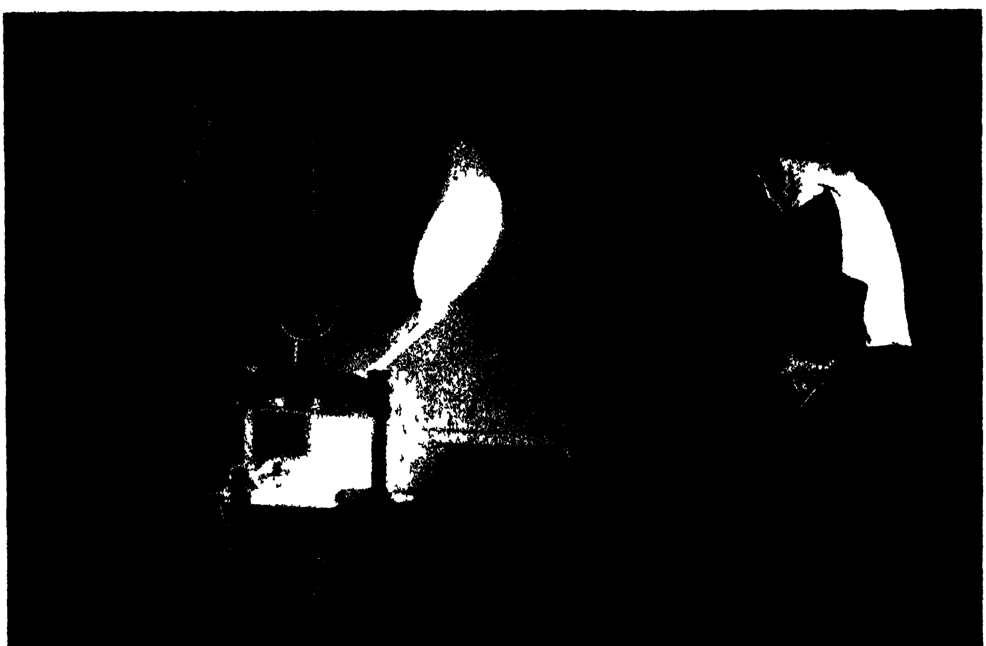


Photo B I S F.

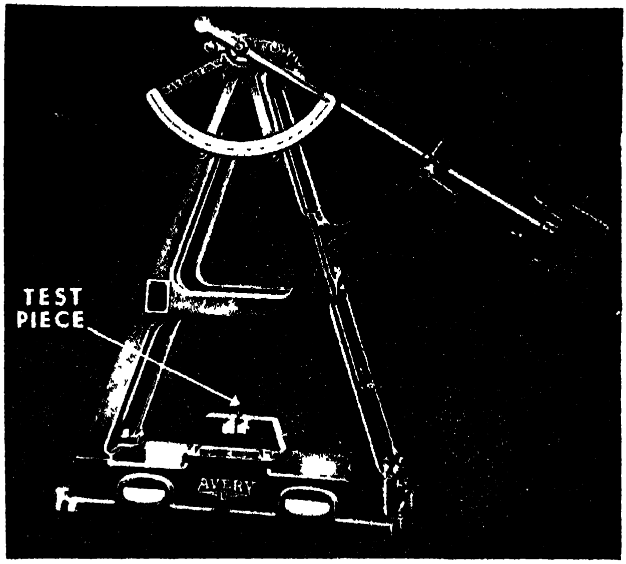
TAPPING A HIGH-FREQUENCY ELECTRIC INDUCTION FURNACE

This photograph shows a high-frequency electric induction fu nace being tapped The old-style crucible furnace has been largely replaced by this modern furnace for the manufacture of very high-quality steels such as those required for the best cutlery and tools, for instance All the old man-handling has been done away with and the entire process is much cleaner and less arduous than the older method.

old man-handling has been done away with and batches of several hundred-weights or even tons of steel may be made. The entire process is much cleaner and less arduous.

It is the high frequency induction furnace which makes it possible to manufacture the remarkable alloy steels used in the gas turbine, the "jet" engine which drives aircraft at 600 miles an hour. These steels work at a red-heat and carry enormous loads without distorting even by a fraction of an inch!

Arc Furnaces and High Frequency Furnaces together produce about 600,000 tons of steel every year in Britain.



TESTING THE TOUGHNESS

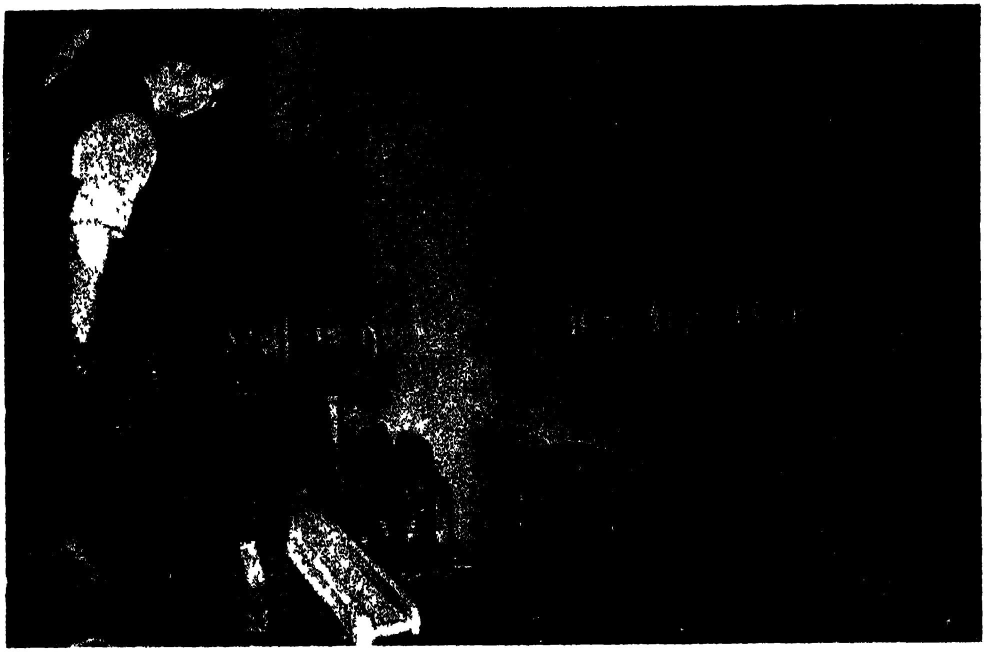
To determine the toughness of steel an Izod testing machine is used. The big weight swings down and snaps the test piece in half; from the distance the weight continues to swing, the energy absorbed by the test-piece in breaking can be calculated.

Photos B I S F

ALL MADE OF STEEL

We still speak of the "iron road" and the "iron horse" when speaking of our railways and locomotives although they have both been made of steel for long years past. Steel can be made very much stronger than iron and the rails seen in this photograph are made of cast manganese steel which withstands tremendous wear. The scene is the railway crossing at Newcastle Station.

OUT OF THE FIERY FURNACE



B I S I

AT WORK IN THE ROLLING MILL

Steel billets are rolled into two general varieties of finished products Sections and Rounds "Sections" are such things as beams, joists and railway lines Here we have a finished rail emerging from the last "pass" in a section mill In front of the rolls are the guides to run the steel between the grooves

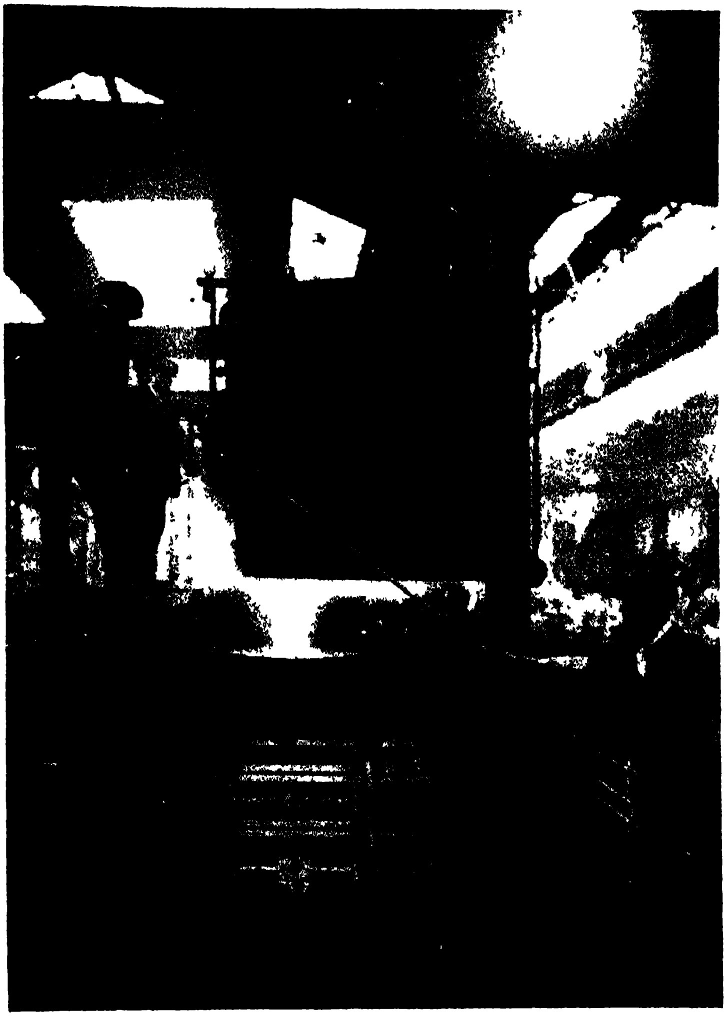
WE have now seen how steel is made, and we may now examine how this white-hot mass of molten metal is turned into something useful.

Steel, as we have said, is our most versatile structural material, we can do a great many things with it. To understand this we may conveniently draw up another "family tree."

- Molten Steel
  - Ingots
    - Rolled Products
      - Rails, Joists, Beams, Etc. ('Sections')
      - Rods, Bars, Wire, Etc ('Rounds')
      - Plate, Sheet, Strip, Etc. ('Flats')
    - Forgings
      - Guns, Boiler Drums, Crankshafts, Tubes, Etc.
  - Castings
    - Wheel Centres, Chain Cables, Gears, etc.

When it leaves the furnace the molten steel pours into a big steel bucket lined with firebricks and called a ladle. This ladle is fitted with a fire-brick nozzle about 1 inch in diameter in the bottom which is plugged inside the ladle by means of a long steel rod surrounded with firebrick reaching up to the top. By means of a lever arrangement this plug or "stopper-rod" can be raised or lowered as required to allow the metal to flow out when wanted.

If the steel is to make castings the ladle is carried into a position over sand moulds which are filled with steel in much the same way that moulds are filled with iron in the iron foundry to make iron castings. The difference is that whereas iron is always poured out quickly over the spout of the ladle, steel is "teemed," as the foundryman calls it, through the nozzle in the bottom, and since the temperature of steel is 300° C. to 400° C. higher than that of iron so much greater care has to be taken in the making of the mould and in the filling of it to enable it to with-



Hadfields Ltd.

MAKING A STEEL CASTING

When steel is to be used in making castings the ladle is carried into a position over sand moulds in much the same way as iron in the foundry. Iron is always poured out quickly, however, while steel is "teemed" through the nozzle in the bottom of the ladle

stand this tremendous heat without cracking up or wearing away and thus spoiling the casting. Among the most important of steel castings are the centres of railway locomotive wheels, spoked wheels which have to withstand constant shocks and strains which would very soon smash cast iron. Another is ships' anchor cables, huge links being cast around each other very ingeniously to make up the length. In heavy engineering there are numerous examples of steel castings, particularly in steels like the enormously tough and wear resistant *Manganese Steel* which cannot be dealt with any other way. The huge jaws of rock crushers or the teeth of mechanical diggers are typical manganese steel castings.

The blades of the gas turbine, which are made of very high quality alloy steels melted in the high-frequency induction furnace, are formed by casting. Since they have to be so accurately shaped they are produced by a technique known as precision casting. This uses the centuries-old "Lost-Wax" method of moulding which was employed by the famous Italian silversmith Benvenuto Cellini in the creation of his masterpieces.

So it is that the combination of modern science and age-old craftsmanship has contributed to Man's conquest of space and time.

Making Steel Ingots

Casting is one way of treating molten steel and makes the finished product in one stage. But only 3 tons out of every 100 tons of steel is so treated, the other 97 tons are first made into ingots and then the solid ingots are mechanically worked into final shape

by two general methods, rolling and forging. Not only can steel be shaped in this way, but the act of working red-hot or even cold steel improves its mechanical strength and toughness to a remarkable degree.

Ingots of steel are made by "teeming" the contents of the ladle into tall, narrow cast-iron moulds usually rectangular in section, sometimes octagonal. The size of each ingot depends on what it is destined to become finally. Steel to be made into wire or thin strip may be cast into small ingots of only about 1 ton in weight, sheets, plates, sections, rails, etc., into ingots of 4 tons to 10 tons, while the really big jobs such as high-pressure boiler drums or naval guns, which are forged, are made from ingots of perhaps 100 tons and more.

Ingots are "stripped," that is, removed from the mould, as soon as they are sufficiently solid, which time varies with size. Sometimes they are further treated in a separate works altogether, in which case they are allowed to go quite cold and are loaded on a railway wagon. More often, however, they are rolled in the same works, and they are immediately put into a furnace called a soaking pit. The ingots in a soaking pit do not get heated up to any great extent, the purpose of "soaking" them is to bring the whole ingot to a uniform temperature. When taken out of the ingot mould the centre of the ingot is still molten, the outside surfaces will be solid and at a red heat, probably about 1,100° C. to 1,200° C. temperature. When the ingot is withdrawn from the soaking pit it should be at an even temperature of 1,200° C. to 1,300° C. all the way through, and at this bright-red heat it proceeds on the first stage of hot rolling.

Rolling Mills

A rolling mill is in effect nothing more than a huge steel mangle, and if you take a piece of Plasticene and put it through your Mother's mangle (when she's not looking of course !) you will get a fairly good idea of what a rolling mill does to red-hot steel. Out of every 10 tons of steel made, 9½ tons are rolled.

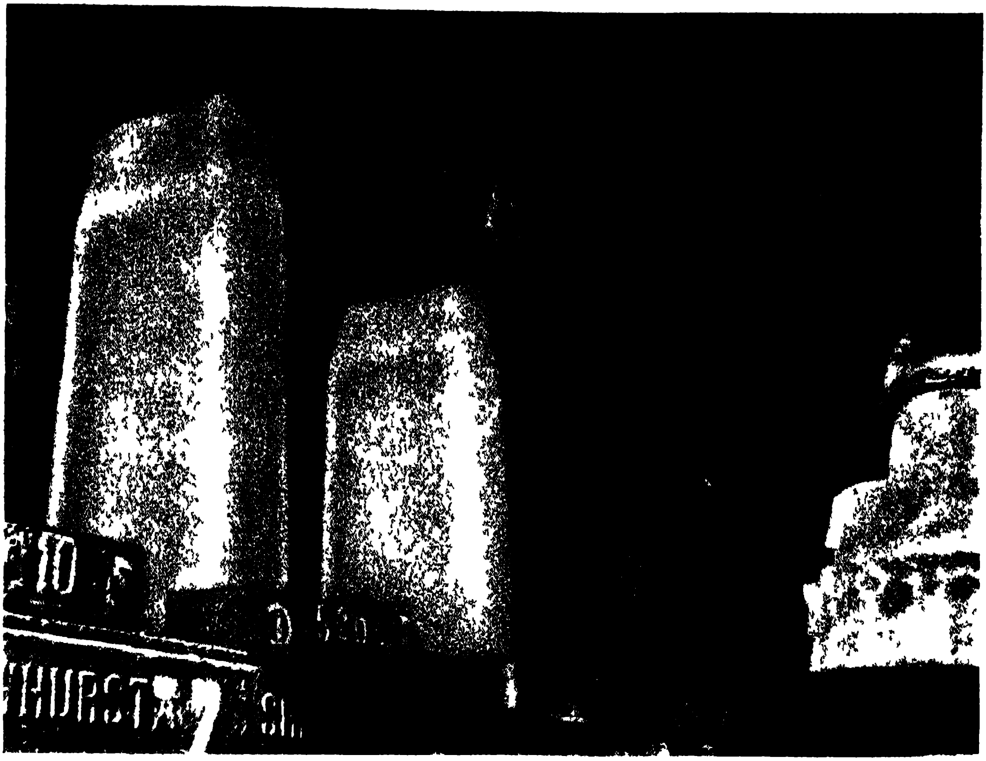
The first stage in rolling is called "cogging-down" and is done in a very large, stout and robust mill called a cogging mill. This reduces the size of the ingot to more manageable proportions, but of course lengthens it enormously. The long "bloom" of red-hot steel as it is called is passed back and forth through the mill until it is down to roughly the correct size, the rolls of the mill coming closer together for each "pass." The weight of the steel is far too much for man-handling of course, so the cogging mill is equipped with long "tables" of electrically-driven rollers on either side, together with hydraulic rams and lifters which run the steel back and forth, turn it on its side, straighten it all by the flick of a switch in the control cabin.

The noise is tremendous, and the shock when the rolls "bite" into the great mass of steel makes the whole building tremble. Sprays of water play on the rolls constantly to keep them cool. Huge electric motors drive the mill rolls, first one way and then the other.

Three Kinds of Rolled Steel

When the ingot has been cogged down the "bloom" is cut into lengths of about 6 feet to 8 feet which are called "billets" or "slabs" according to their shape. These are generally put into another furnace to get rather hotter before being rolled any more, since the steel may have cooled quite considerably during cogging down. If steel is rolled too cold it is not plastic enough and may crack.

Steel billets are rolled into two general varieties of finished products—"Sections" and "Rounds," and slabs are rolled into "Flats." "Sections"



WHEN THE INGOTS ARE STRIPPED *B I S F*

Ingots of steel are made by "teeming" the contents of the ladle into tall narrow cast iron moulds, the size depending on its ultimate purpose. This picture shows the ingots as they are being stripped. The moulds are lifted off the red-hot ingots as they rest on the ingot bogies.

are such things as beams and joists for bridges, steel-framed buildings, ships' frames, etc., and of course railway lines.

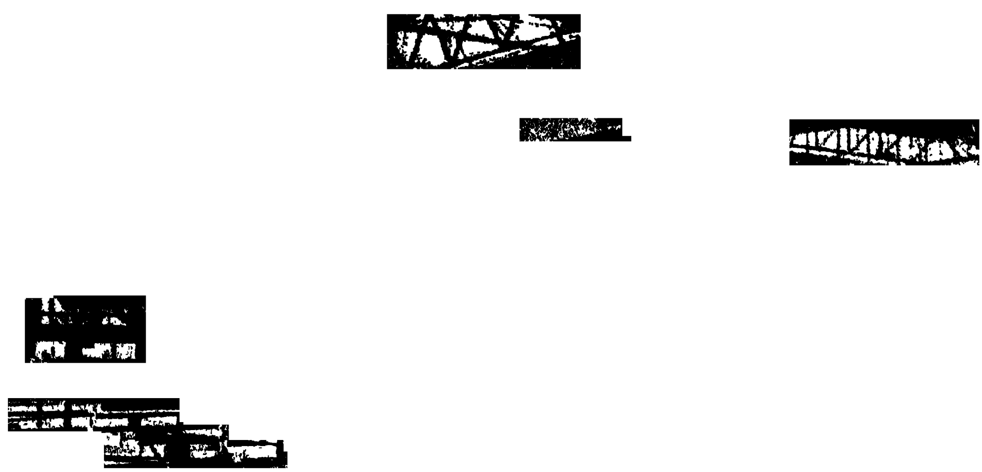
"Rounds" are long steel rods such as those used for reinforcing concrete, other rounds are used for making bolts and nuts, and the smaller sizes may be later "drawn" through dies to become very small indeed and made up into steel hawsers. Most important of all, however, are "Flats," especially steel plates for locomotives, wagons, ships, etc., and sheets which are consumed in enormous quantities in the manufacture of motor cars and for making the tin cans which preserve food. "Tinplate" is thin steel sheet with a very thin layer of tin laid over the surface on either side.

Rolling mills which roll billets into sections and rounds have rolls with matching grooves cut into them in such a way that the steel passes through a series of cleverly shaped holes, finally emerging in the form that is wanted. The rolls do not move any closer together during the progress of rolling, the steel is guided into successively smaller grooves to reduce its size and bring it to shape.

In rolling plate and sheet, however, smooth rolls must be used. The steel is passed back and forth through the rolls of the same mill which are brought closer and closer together. To avoid constant reversing the "three-high" mill with three rolls on top of each other may be used, the steel first going between the middle and lower rolls and returning between the middle and upper ones. Thus the mill runs constantly in one direction but the steel is reduced in thickness at each "pass."

IN THE MILLS AT MARGAM

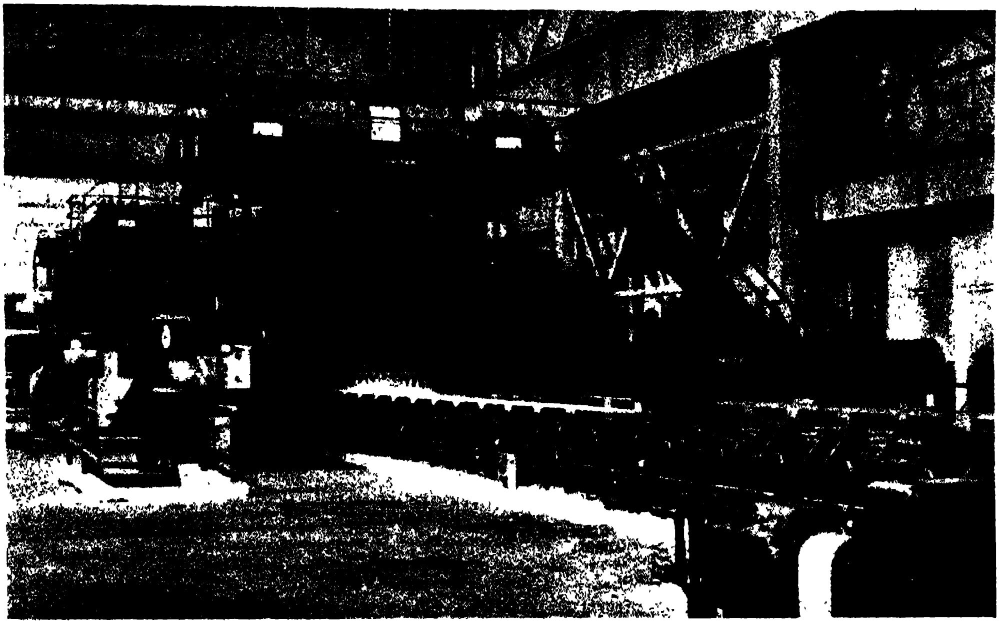
Much of the steel in use to-day is in the form of plate and sheet, and in this picture we have a view of the giant cogging mill at Margam Abbey Works. This rolls the ingots to slabs. After shearing and trimming the slabs are re-heated and rolled in the continuous mills which are seen on the opposite page.



Photos: Steel Company of Wales.

Red-hot ingots are passed to and fro through heavy rollers which roll the ingot into a slab of anything up to 60 inches wide and 8½ inches thick. Here the steel is seen passing through electrically operated slab shears, after which a separate edger mill will give the slab its correct width.

TOWARDS THE FINAL STAGES



After passing through a reheating furnace a slab is carried on rollers to the Hot Strip Mill. First it passes through a scale-breaker which removes the scale formed in the reheating furnace. It then passes through the four stands of the "roughing" mill. Here the slab is seen entering the first roughing stand.

Photos: Steel Company of Wales.

Here is the last stage in rolling steel strip in the 80-inch Continuous Strip Mill. This shows the Finishing Stands and run-out table. When it emerges from the last Finishing Stand the strip, travelling at a speed of up to 2,000 feet per minute, is carried down to one of the coilers.

The Continuous Mill

For the manufacture of the enormous quantities of steel sheet now demanded by the motor industry the continuous mill is used. Instead of passing the steel back and forth through a single stand of rolls, as many as five stands are placed immediately one behind the other and the steel goes straight from one to the next. The speed of rolling is very fast, the steel when it emerges from the last stand of rolls being shot out at something like thirty miles per hour. To see a long flat "snake" of red-hot steel tearing up the shop at this speed, to be caught and coiled up safely in a mechanical coiler is a wonderful experience!

Not only is this method of rolling steel extremely fast but it makes the sheet tough and strong. In practically one single cold pressing operation in the motor-car factory the sheet is converted from a flat piece of steel into a moto car body. Only steel which has been made to a very closely-controlled analysis and rolled in this fashion can stand treatment like this without cracking or winkling.

Small rounds and sections may also be rolled in continuous mills, in this case with grooved rolls. The steel emerging from the last set of rolls cannot be coiled, but is cut to lengths by an extremely ingenious machine called a "flying shear," which actually chops the steel while it is moving. Heavier sections such as rails are cut to length by a hot saw, a circular saw which bites through the red-hot steel in a matter of a few seconds.

In modern rolling mills of course all the handling of the steel to and from the mill is done mechanically on the long roller tables. Brute strength is not necessary, but a high degree of skill and speed in adjusting the mill setting and working the control levers most definitely is required.

Forging Red-hot Steel

If the steel is to be worked up into a shape impossible to make with rolls, and if it is needed in a much stronger condition than is possible when it is cast, then the ingot, or the billet in the case of a smaller item, is forged.

Forging is what the blacksmith does to red-hot wrought iron on his anvil, for steel we now use the hydraulic press and the steam hammer. In the first case we give the steel a mighty squeeze, in the latter we give it a series of hard blows. Another method of forging which is used for making large tubes is extrusion, where the plastic steel is made to flow through a hole with the centre portion blocked out and so take up the shape of a tube in a single pressing operation. Of course enormous pressures and very strong apparatus is needed for this. A 2,000-ton forging press is illustrated on page 78. The ingot rests on the "anvil" down below and the ram on which "tools" of various shapes and sizes may be bolted, slides up and down the four vertical pillars, being raised and lowered by tremendous hydraulic pressure. As forging proceeds the ingot is turned a little bit further round at each squeeze and slowly takes up the shape required. In the case of a large forging of this kind it will have to be re-heated a number of times during forging. Special furnaces with removable front doors are used for this purpose, since the front of the furnace has to be torn down and re-bricked up every time such a large ingot is taken in and out.

The steam hammer is used for smaller items, and the manipulation of the billet is usually done by hand. The hammer is also used for drop forging, where both the hammer and the anvil carry a die, that is a shallow mould of very tough steel, the die being in the shape of the final forging. The red-hot billet is laid over the die on the anvil and repeated blows from the hammer cause the steel to flow into the dies and take up the final shape desired. Motor-car crankshafts are

B I S F

THE MEN AT THE CONTROLS

We have seen the giant machines at work and here are the men who control them Those seen in this photograph are at the controls of a "cogging" mill Their eyes never leave the mill and they work the control levers by touch and at a tremendous speed

produced in very large numbers by drop forging. Hammer forging is, of course, a noisy business as you can imagine, but is a good deal faster than press forging.

Making Steel Tubes

Steel tubes may be made in various ways according to their size. Medium-sized tubes are extruded in one operation in the way already described. Large tubes (apart from the very large one being forged on page 78) are made in what is known as a Pilger Mill by a process which is a kind of cross between forging and extrusion. A round billet which has first been "burst," that is spun around and squeezed to make a hole appear along its central axis, is pushed into a mill, the rolls of which are eccentrically shaped and which revolve in the opposite direction to the movement of the billet. These rolls both squeeze and reject the billet which is then turned through a right angle and pushed into the rolls again. This constant squeezing, rejection, turning and squeezing again slowly forces the steel into the shape of a tube.

Small-sized tubes are made from rolled steel strip in a continuous operation. The strip is caught up by a machine, curled round until the two edges are almost touching, the edges are given a rapid heating and then squeezed together to make a joint. Provided the steel contains no more than a very small amount of carbon (*i.e.*, it is a very "soft" steel) the edges will fuse together satisfactorily. Automatic devices cut the tube to length as it emerges continuously from the outgoing end. "Pluto," the famous pipe-line which carried petrol underneath the sea during World War II, was made in this way.

Heat Treatment of Steel

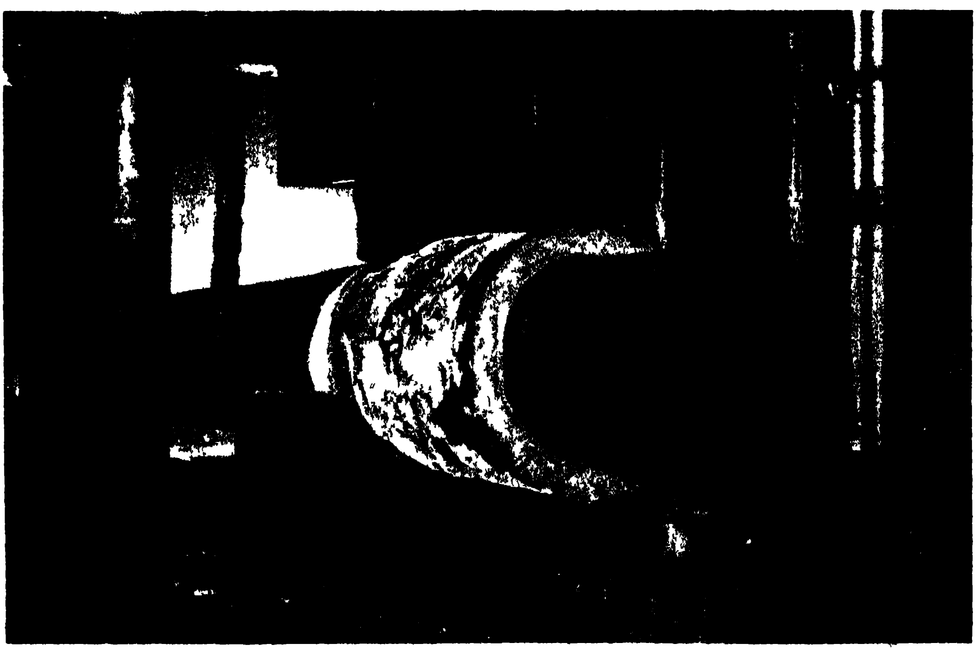
Steel, and especially alloy steel, is capable of varying its properties according to the way in which it is heated and

cooled. By a combination of the right quantities of carbon and alloying elements with the right " heat-treatment " we can make a steel suitable for almost every conceivable job.

Ordinary " carbon " steels, such as are used for making rails and joists and similar sections are " normalised." This is simply allowing them to cool in fairly still air after they leave the rolling mill. This imparts a certain degree of hardness and a certain degree of toughness, and before the rails are allowed out of the works a sample will be sawn off and tested for hardness and toughness. Only if the properties are sufficiently good will the rails be " passed " for service. Like men joining the army they have to be pronounced " fit " for the arduous job they do.

Steel may be made extremely hard by " quenching," that is, plunging it red-hot into water or oil and cooling it very rapidly, but such treatment is liable to make it brittle and it may crack easily. The necessary toughness may be recovered by " tempering," that is, letting the quenched steel soak for a period in a gentle heat of about 400° C. to 500° C. The armour-plate in tanks and battle-ships, which has to be hard enough and tough enough to withstand shot and shell, is given an elaborate quenching and tempering treatment. It, too, is very carefully examined and tested before it can be used.

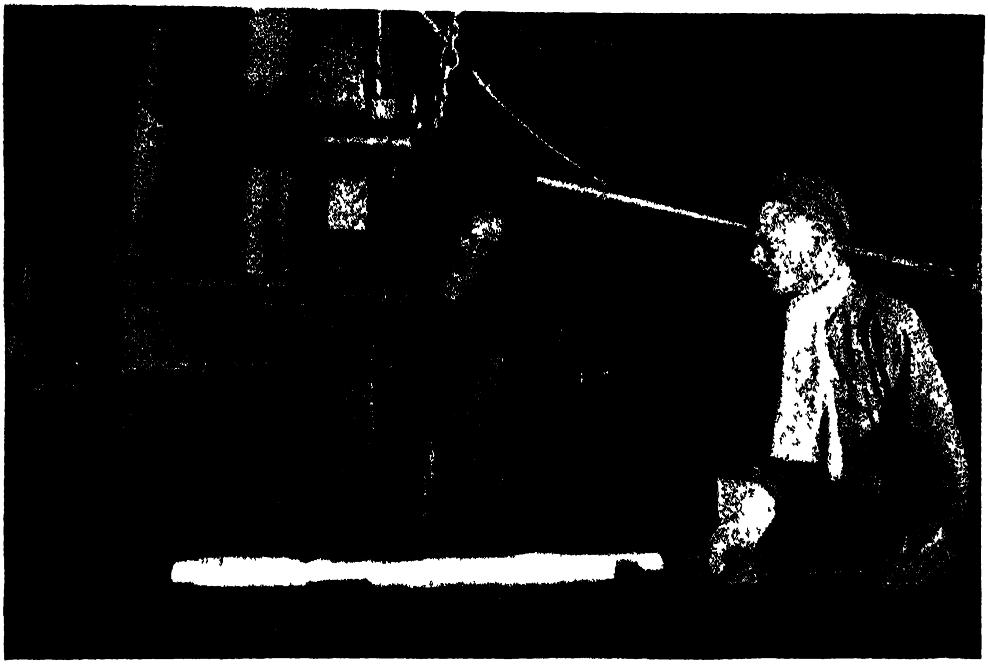
Another thing we can do with steel is to " case-harden " it, that is, make it very hard on the outside but maintain a degree of softness and toughness inside. This is done by partially " cementing " it. A fairly low carbon steel, usually containing some nickel and chromium is immersed in charcoal or in a chemical called potassium cyanide and is heated for a certain length of time. This causes some of the carbon in the charcoal or cyanide to diffuse into the steel



B I S F.

A 2,000-TON FORGING PRESS IN ACTION

When the steel is required in a much stronger condition than is possible when it is cast, then the ingot is forged. In this photograph a high-pressure boiler drum is being forged on a 2,000-ton hydraulic press.



B I S F

UNDER THE STEAM HAMMER

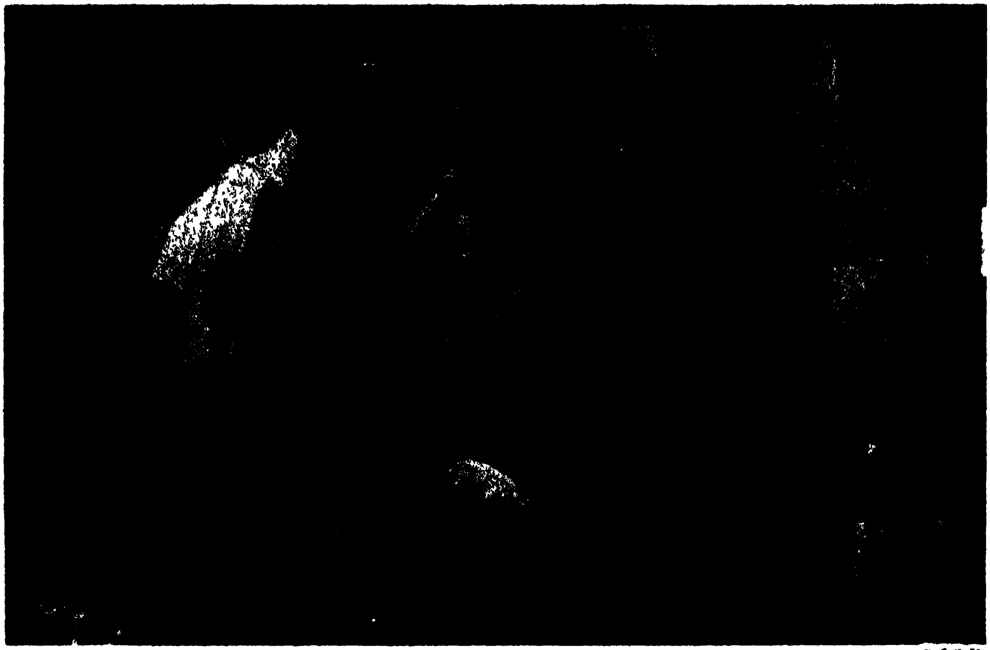
Here we see a light forging being made under the steam hammer. The boy operates the hammer while the man works the steel into shape. For these smaller forgings the manipulation of the billet is usually done by hand.

forming a high carbon layer on the outside surface. Before this becomes too deep the steel is taken out of the furnace and is normalised and tempered. The high carbon outer layer, which is extremely sensitive to heat treatment, becomes very hard, while the inside remains tough. The kind of treatment is given to the teeth of large cog wheels, the rubbing surfaces are made very hard and resistant to wear, the body of the tooth remains tough and able to carry the load without cracking.

Cutting and Joining Steel

Finally, we may take a look at the ways in which steel, after we have rolled it into sections or plates or bars, can be utilised to construct machinery, bridges, ships, cars, locomotives and all the rest.

The first thing necessary is to cut the pieces of steel to the right length and shape, and for this we now possess a most valuable and useful tool in the oxy-acetylene cutting torch which can cut through steels over a foot thick. The cutting torch works with a mixture of two gases, oxygen and acetylene. The acetylene is burned in a flow of oxygen and this makes an extremely hot flame which is played on the steel and rapidly brings a small area to a red-heat. Then another and finer jet of oxygen is turned on which actually shoots through the middle of the oxy-acetylene flame and strikes the red-hot steel. At this temperature the oxygen very rapidly turns the steel to molten iron oxide which is actually blown out of the steel by the force of the jet. The operator then moves the torch slowly along and the jet of oxygen cuts a narrow slit in the steel. If the torch is mechanically guided a very smooth cut can be made. A flood of sparks pours out of the steel, and the operator must wear dark goggles to enable him to see what he is doing and protect his eyes from sparks.



B.I.S.F.

DROP FORGING IN PROGRESS

In drop forging both the hammer and the anvil carry a die, a shallow mould of very tough steel, the die being in the shape of the final forging. The red-hot steel billet is laid over the die on the anvil and repeated blows from the hammer force the steel into the final shape desired

Having cut our steel to size it must be joined together in the way we want it. This can be done by drilling holes in the steel and either joining the pieces with rivets or nuts and bolts. A rivet is a little piece of steel shaped like a mushroom. The " stalk " of a red-hot rivet is pushed through the matched-up holes in two steel plates, and protrudes a short distance. One man then " holds-on " the head while on the other side a man hammers the stalk and flattens it out to hold the rivet in place. As it cools and contracts the rivet makes a very tight fixture. The big steel girders supporting railway bridges are commonly made up of a number of steel plates riveted together, and the steel plates of ships' hulls are commonly riveted to the frames and to each other.

Alternatively, nuts and bolts may be used, but these are, of course, very much more expensive and are used only where the joint must be undone again, such as in joining railway lines together with " fishplates." When the track is worn out the joints must be released or the rails cannot be pulled up easily.

Electric Arc Welding

Over the last twenty years or so another method of easily and rapidly joining steel together has been developed and perfected, the process known as electric arc welding.

We saw when we considered the electric arc furnace how an electric arc may be struck between two pieces of steel and may actually melt them. Another practical use is made of this in arc welding. Two pieces of steel to be joined are brought close together and held firmly. Sometimes the edges are " bevelled " to form a groove. The welder then takes a rod of steel about ½ inch in diameter, and often coated with a special material, and attaches it to one terminal of a powerful direct

current dynamo. The pieces of steel to be joined are connected to the other terminal. The welding rod is then momentarily touched against the steel and withdrawn and an arc is formed. This melts the steel of the welding rod, and to a lesser extent, the steels being joined together. Drops of molten steel from the rod fall into the space between the two pieces of steel, fuse with molten steel from either side and then as the rod and arc are moved slowly along they solidify to form a solid and uniform joint. Welding in this manner is now very widely used for joining steel plates, castings and sections, both large and small sizes. It is quick, cheap and convenient, since no drilling and matching of holes is required. You must never look directly at the arc, though, as it is very bad for your eyes. The welder watches his work through a piece of dark glass set in the middle of a special piece of stout sheeting which protects both his eyes and his face from the dangerous ultra-violet rays.

Wellman Smith Owen Eng Corp Ltd

MAKING STEEL TUBES

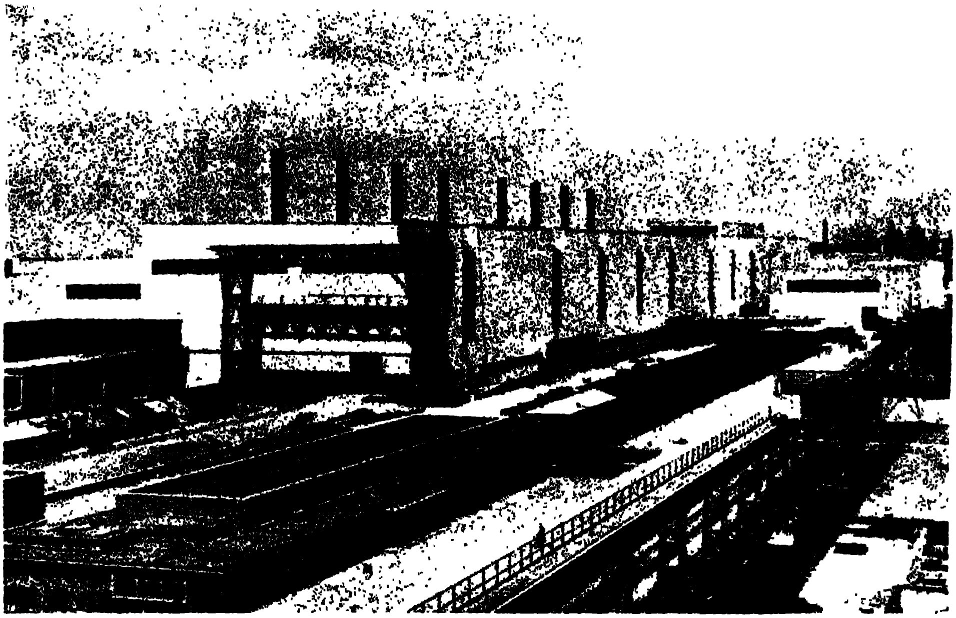
In making large tubes the method of forging which is used is known as the extrusion process The plastic steel is made to flow through a hole, with the centre portion blocked out, and so take up the shape of a tube in a single pressing operation Enormous pressures and very strong apparatus are required

Our Most Dependable Metal

When Benjamin Huntsman made up his mind to try his hand at steel-making he did so because he wanted to make clock springs which were reliable. He was tired of hearing his customers complaining that the springs of his clocks didn't last properly and demanding that new ones be fitted. Right from the very start, therefore, steel was designed to be something on which the user could depend.

To-day steel in all its numerous

A SOUTH WALES STEEL WORKS

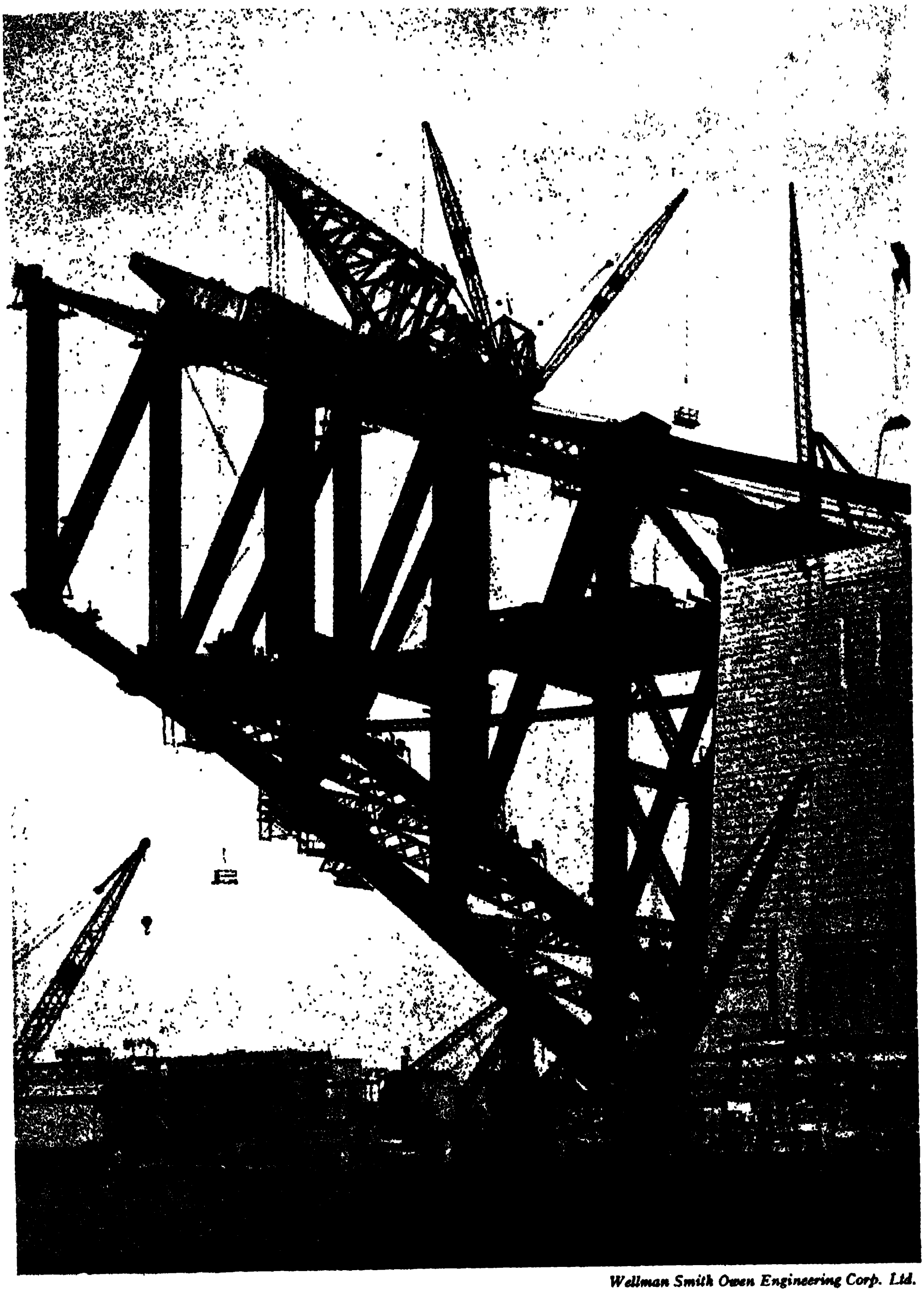


The Steel Company of Wales was formed when four great companies engaged in the steel and tinplate industry pooled their resources. One outcome was the erection of the largest steel plant in Europe: the Abbey Works at Margam, Port Talbot. This photograph shows the Melting Shop Building; the eight chimneys correspond to the eight open hearth furnaces inside.

Photos: Steel Company of Wales.

The whole site of this new works, built on waste land near the sea where special grass was planted to bind the sand together, covers an area three times the size of Hyde Park, and is some four and a half miles long. Some idea of the land on which it is built is shown in this picture of the Cooling Tower and the Melting Shop ramp at Margam.

ALL MADE OF STEEL



Wellman Smith Owen Engineering Corp. Ltd.

In this picture we see some finished examples of the products of the steel works. The main structure shows the girders forming the spring arch of the famous Sydney Bridge in Australia. On top of these girders is a giant creeper crane, so called because it is able to creep along the top of the girders as the work of construction on the bridge goes on.

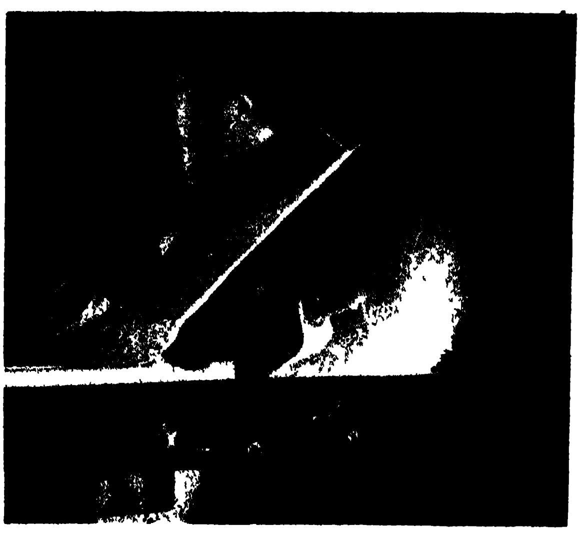
forms may rightly claim to be not only our most versatile material but also our most dependable. Everything in the manufacture of steel is kept under control, particularly the chemical analysis which plays such a large part in determining the properties of the final metal. If you ever have the good fortune to visit a modern steelworks you will see on almost every side instruments and devices used to control the process, and one of the most important places in the whole works is the chemical laboratory where the samples of the steel are analysed.

Samples will be taken from the molten metal during refining and the chemists will check the amount of carbon, silicon, manganese, sulphur and phosphorus they contain, and if "alloy" steels are being made then chromium, nickel, molybdenum and vanadium will be "assayed" as well More samples will be taken when the steel has been rolled and treated, and if any analysis shows that a "cast" of steel is of the wrong chemical composition then all the steel made from those ingots will be stopped from going to the customer.

Next door to the chemical laboratory you will probably find the "test-house." Here the samples of the steel are examined for their mechanical properties. The "tensile strength" of steel is determined by finding out how much force is needed to pull apart a sample of steel of a square inch in section. Hardness is measured by forcing a ball bearing or a diamond-shaped piece of very hard steel into the polished surface and measuring the indentation. Toughness is determined by breaking a sample by means of a heavy swinging weight and measuring how much the swing of the weight has been reduced. Only a simple calculation is needed to work out how much energy is consumed in breaking the steel sample.

In the same building the works metallurgists will be busy examining the inside of the samples of the steel through microscopes. What is called the "microstructure" of the steel is very important in determining its properties and making certain that the heat-treatment has been done properly.

All this care ensures that the steel will never let the customer down. Next time you see an express train thundering past—look down at the rails and especially at the rail joints. Watch how the rails bend under the weight and see how the wheels "hammer" the rail ends. If you count the number of wheels in each train and then find out how many trains pass that particular spot every day you can find out just how many hammerings that steel rail has to put up with every twenty-four hours. It is the dependability of steel which ensures that this rail and all its fellow rails throughout the length and breadth of the railway system, carry the load and go on carrying it.

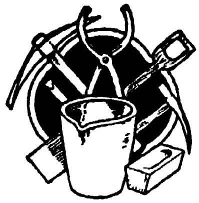


G.E.C.

PROTECTING THE WELDER

An electric welder is seen here at work. The arc is "struck" at the end of the welding rod, and the worker watches it through a piece of dark glass, set in the shield. This protects his eyes and face from the harmful ultra-violet rays.

Treasures Won from the Earth's Crust



Metals that Serve us in A Hundred Ways

Transvaal Chamber of Mines

WEIGHING BARS OF SOLID GOLD

The largest gold refinery is at Germiston, near Johannesburg, centre of the world's richest gold fields. The precious metal is extracted from the ore by various processes and then formed into bars of almost pure gold. Our photograph shows the scene when these bars are being weighed. Approximately a bar contains 400 fine ounces troy and the value of one bar would be roughly about £3,400

THAT PRECIOUS METAL—GOLD

FEW words stir men's minds so deeply as "gold." Gold stands for wealth, power, royalty, excellence, value. Since the earliest days of history gold has been regarded as very precious, the metal fit for kings and priests to wear. Gold is the first metal mentioned in the Bible (Genesis ii. 11). The Tabernacle of the Israelites was richly decorated with gold; so, too, was the Temple of Solomon. In his Book of Revelations, St. John visions the Heavenly Jerusalem as constructed of pure gold: nothing baser seemed worthy.

Ancient legends are full of references to gold. You have read, for example, the story of Jason and the Golden Fleece; and that of Midas, King of Phrygia, who was granted the magic power of turning everything he touched into gold. We still speak of an extremely wealthy person as a Midas.

Almost Indestructible

Gold is a very beautiful metal. It is also practically indestructible, being affected by but very few other substances. The oxygen of the air does not harm it, so that it never tarnishes, and a thin layer of it gives a sure and beautiful protection against corrosion.

Gilding has been practised from the earliest times, being made possible by

the ease with which gold, the most malleable of all metals, can be beaten out into thin, unbroken sheets. The gold-beater flattens an ounce of it into 100 square feet of "leaf"; and an ounce has a very small bulk, since gold weighs nineteen and one-third times as much as water and is over two-and-a-half times as heavy as iron. It has been stated that it is possible to make gold leaf so thin that 1 ounce of it would cover 10 acres of ground!

Its beauty, permanence, ease of working and rarity have combined to render gold so greatly desired a metal that many dreadful deeds have been done to acquire it, and the alchemists laboured to find the Philosopher's Stone which would change baser metals into gold. The last quality—rarity—has perhaps had most influence. If gold were discovered in quantities equal, say, to those of copper, its present value would disappear. It has been estimated that all the gold produced since the discovery of America in 1492 would not amount to 25,000 tons.

During the four centuries elapsed since then the population of the world has increased very greatly; and, in spite of the fact that the gold output also has increased, there seems no likelihood of the metal ever catching up with the demand for it, or of its value going down. The steadiness of its price has made gold the most reliable standard of value by which to set the prices of all other commodities. In the form of coins, gold is a very convenient medium of exchange. During the forty-seven years following 1870 the Royal Mint in London converted into coins gold worth over £400,000,000. In 1914 the value of all gold currency in circulation throughout the world was put at about £1,660,000,000.

To be suitable for the hard wear that it gets as coins, jewellery, watch-cases, and other commercial articles, gold is alloyed with copper or silver. Pure gold is 24-carat gold. A sovereign is of 22-carat gold; that is, it contains twenty-

Specially drawn for this work.

GOLD MINING IN THE KLONDYKE

The men who won gold in the Klondyke had to work under conditions which only those possessed of the finest physique could stand. The ground had to be thawed before digging could begin. The above illustration shows miners at the windlass bringing up the earth excavated from the shaft

THE TRAIL OF '98

Specially drawn for this work.

For three or four years, between 1897 and 1901, Klondyke, a district in Yukon Territory, north-western Canada, was the goal of a multitude of men, and women too, who were prepared to risk everything, even life itself, in a wild rush to stake out gold-mining claims. From this picture we gain some idea of the terrible hardships encountered by the miners in their journey over the Chilkoot Pass. Fortunes were made in the Klondyke, but many men and animals fell by the wayside, victims to exhaustion and the intense cold.

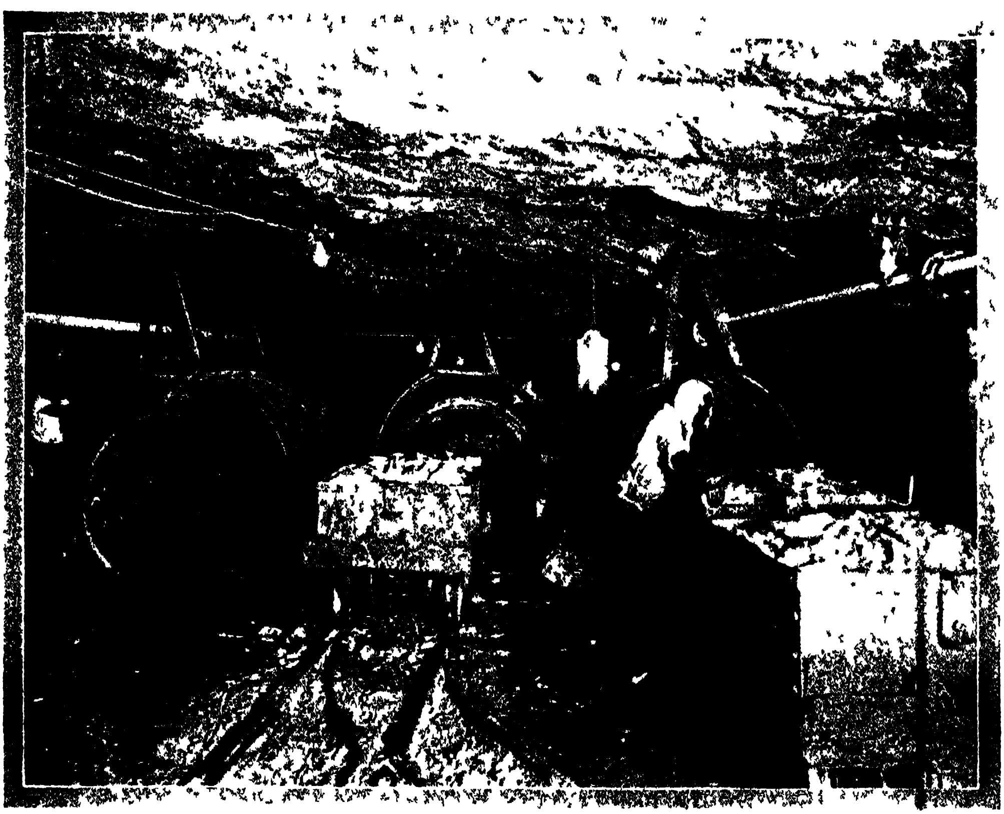
two parts gold out of twenty-four, the other two parts being another metal—copper Jewellery is usually of 18-, 15- or 12-carat gold A great deal of gold is used in the arts Much is locked up as ingots (bullion) in banks, and may be passed in this condition to and fro between countries for many years in payment of debts Of the remainder, the bulk is being used or hoarded away as coin

Washing for Gold

Gold has often been found as loose grains, flakes, or lumps, called nuggets, in the sand and gravel which form, or once did form, the beds of streams and rivers Gold occurring thus is called alluvial gold It is usually separated from other substances by means of water.

"Washing," in its simplest form, consists in placing some of the gold-bearing sand or gravel in a shallow iron pan with water and tilting the pan slightly while giving it a circular motion. The lighter portions of matter are flicked over the lip with the water, while the heavier gold particles and pebbles settle The pebbles are picked out by hand and the washing is continued till only a little sand remains with the gold The residue is carefully dried, and the earthy dust can then be blown away

Where large quantities of material have to be treated, a sluice is used This is a long sloping wooden trough, with



Transvaal Chamber of Mines

AT WORK IN A SOUTH AFRICAN MINE

Most of the gold of the world is now obtained by deep mining from quartz rock, the superficial deposits having gradually been worked out Primitive man obtained quite considerable quantities of gold from deposits near the surface, but to-day gold-winning involves deep mines and machinery, as seen in this picture of men despatching the gold bearing quartz for crushing in the Modder Deep Levels of the South African Rand

WITH THE GOLD SEEKERS

Topical Press

Here is another scene of men at work in a gold mine but this photograph was taken in Australia The men are working some 700 feet underground at the Red White and Blue Gold Mine at Bendigo, Victoria They are using a pneumatic drill for the removal of gold bearing quartz the white reef of which is visible in the background It has been stated that miners who follow a big quartz reef successfully can earn wages of £30 a week and over

crossbars, named riffles, nailed to the bottom. A stream of water flowing through it carries away the rubbish. At intervals a "clean-up" takes place. The gold, whether "free" or amalgamated with quicksilver poured into the trough before operations began, to absorb it, is scraped from behind the riffles and washed in a pan. If quicksilver has been used, the amalgam is heated in an iron retort until the quicksilver passes off as gas into a condenser, where it turns again into liquid. Only the pure gold is left behind in the retort, in a very open or spongy condition. It is melted down into solid bars for sale.

The ease with which alluvial gold can be recovered, and the possibility of striking rich "pockets," or deposits, and nuggets of it, has caused a rush of miners and all kinds of other people to any district in which it has been discovered.

Mad Rushes for Gold

Stories of the great gold-rushes during the latter half of the last century seem almost incredible in these days when gold-mining has become a great industry. There are still alluvial deposits of gold but big finds are unlikely. Long before history was written man regarded gold as the most precious of metals and the search for it has never ceased.

To-day the recovery of gold from the earth is a job for expert metallurgists and mining engineers. The lone prospector has disappeared and the well-organised mining company has taken his place.

The first of the great historical "gold-

South African Railways.

TAKING SAMPLES FOR TESTING

There has always been a certain amount of chance about the discovery of gold and in striking a rich vein of quartz, but in these days as little as possible is left to chance. In the picture above an expert is taking samples of the reef so that it can be properly tested for gold content. If the yield is poor then the reef is abandoned and another reef showing better prospects of a profitable yield is sought.

Commonwealth of Australia

SLUICING FOR GOLD

This photograph, taken in Victoria, Australia, shows another method of winning gold. A deposit of gravel is being broken up and washed away by a large jet of water, and made to pass through a succession of sluices in which the gold that it contains is trapped

rushes" followed the finding of gold in a channel being cut for a water-mill on a tributary of the Sacramento, in California. The discovery was made in January, 1848. The news of it spread like wild-fire all over the continent of North America. People poured into San Francisco in thousands. Some came by ship round Cape Horn; others came overland across the mountains, suffering great hardships.

The tracks taken across America by the immigrants were strewn with the bones of oxen and horses, and the wrecks of waggons.

The "rush" lasted about five years and the lucky ones made rich strikes, washing out thousands of pounds' worth of gold in a few weeks. Most of the miners, however, barely made a living, or soon quitted the country in disgust. A considerable amount of gold was won, however, before the shallow deposits had been worked out.

Among the Californian gold-seekers were many Australians One of these thought that some of the districts of his home-country were very much like those in which Californian gold deposits occurred. He returned to Australia in 1850 to see if he could find gold there, and discovered it in 1851 near Bathurst, New South Wales, about 100 miles from Sydney. A terrific stampede took place. Sydney was left almost deserted. The same year gold was found at Ballarat, in Victoria, and a similar fate overtook Melbourne.

Fortunes were made by lucky folk very quickly, for the Australian gold was coarse, and a single stroke of a pick might reveal a nugget worth a large sum. One day in 1851 a black shepherd

walked into Bathurst with a lump of gold that fetched £4,000. The discovery of other great nuggets from time to time helped to sustain the gold fever. In 1858 a nugget, suitably named the "Welcome," was dug up. It weighed 138 *pounds*, and was valued at well over £8,000 at that time, but the price of gold has risen considerably since then. An even larger one, "The Welcome Stranger," scaling 141 pounds, appeared some years later.

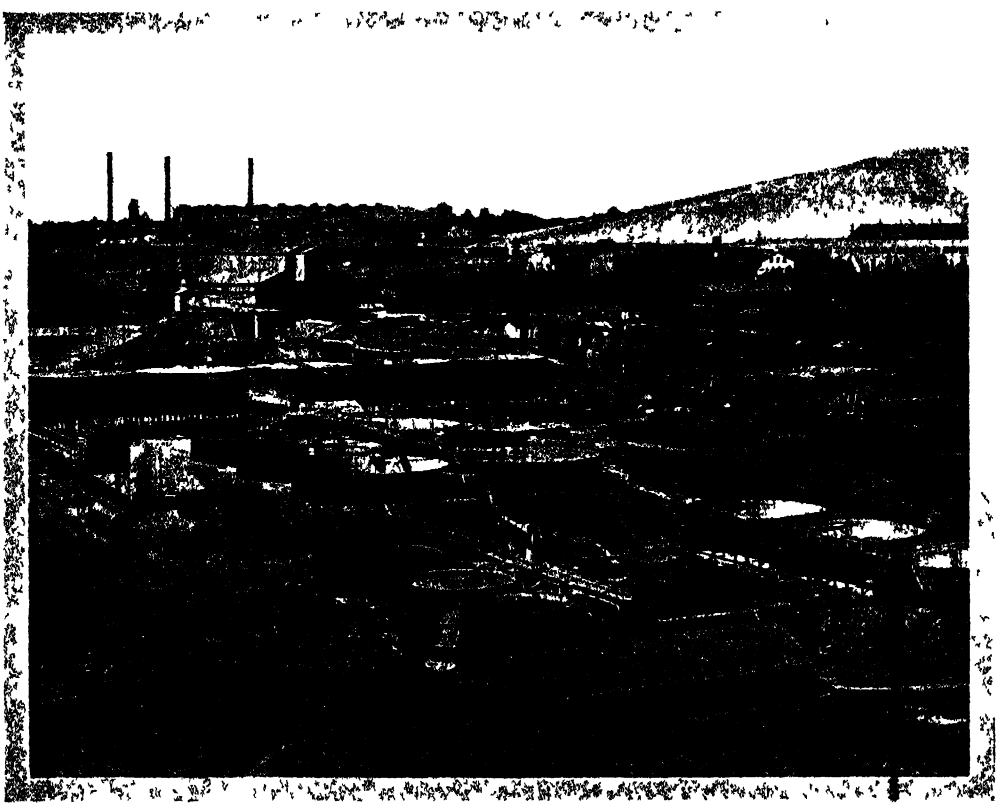
In the "Gold Boom"

In two years the diggers unearthed over £20,000,000 worth of gold. The output then fell off, but by 1895 gold to the value of over £300,000,000 had been produced in Victoria, New South Wales and Queensland, where gold was found in 1860.

Australia experienced another "gold boom" in 1882, when gold was discovered in the northern extremity of Western Australia; and yet another in 1892, when large deposits were found round Coolgardie, about 350 miles east of Perth, the capital.

Then, in 1897, came the rush to the Eldorado of the North, the wonderful Tom Tiddler's Ground in the part of North-West Canada and Alaska through which the great River Yukon flows. Australians who joined in it exchanged the great heat of their own country for the arctic winters of the frozen North.

The story of this rush is much the same as that of earlier rushes: great



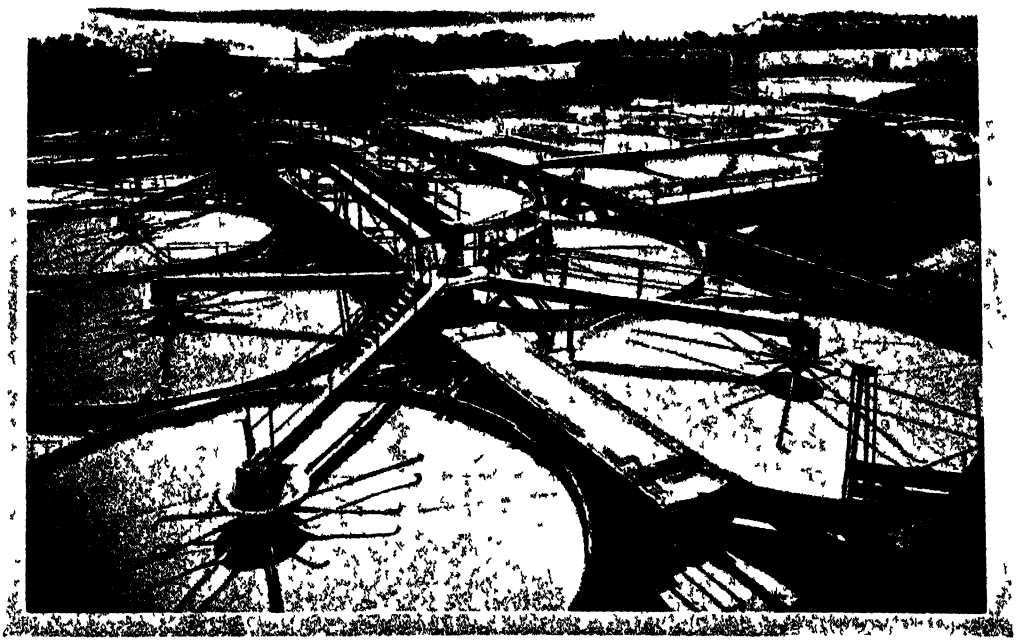
South African Railways

A GENERAL VIEW OF CROWN MINES, JOHANNESBURG

Even at the beginning of this century, and for long ages before, the winning of gold had been largely a matter of individual effort. Stories of good fortune and grim despair have been told of the great gold rushes. To-day, gold-mining is a big, well-organised industry and some idea of the extent of the works erected is given by this picture of a well-known South African mine.

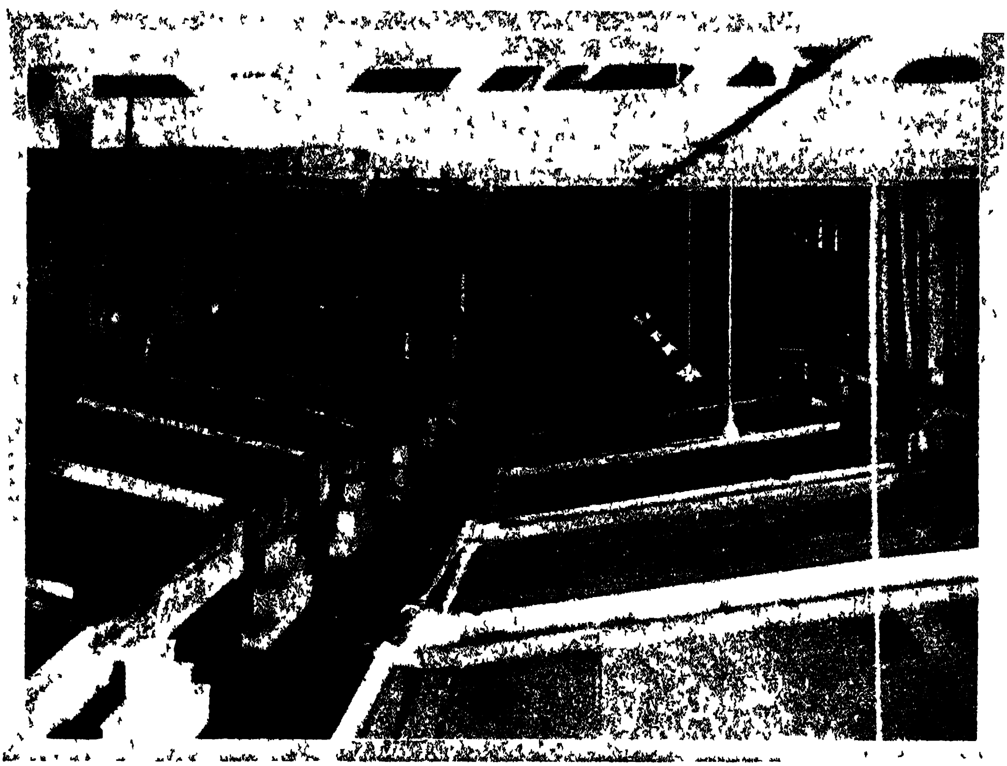
STAGES IN WINNING THE GOLD

When the gold bearing quartz has been mined, it is broken up into fine powder by heavy stamps which are in effect powerful grinding machines The powder is treated with mercury and passed on to the cyanide tanks Our picture shows a stamp battery at a Johannesburg gold mine



South African Railways

Here we see the cyanide tanks at the gold-mine Most of the powdered ore is brought to these tanks which contain potassium cyanide Zinc is also added during the process and the deposit which forms at the bottom of the tank is now nearer the stage when it will be pure gold



South African Railways

ANOTHER PROCESS IN GOLD-WINNING

Not all the powdered quartz from the stamp battery is conveyed to the cyanide tanks as some of the dust containing particles of gold is collected and discharged on to corduroy blankets, as seen in the picture above. Over these a gentle stream of water trickles evenly. The heavy particles of gold remain in the corrugations while the light sand is washed away

hardship, some enormous fortunes and many disappointments. Easily-reached alluvial deposits are soon exhausted. After the cheaply-won gold has been got, operations may be taken up by mining companies using dredgers to wash at a profit large quantities of gravel containing only a small amount of gold. Other companies wash down river banks with powerful jets of water into large sluices.

In many districts the mining of alluvial gold has been followed by the mining of ore containing gold.

About Reef Mining

Various kinds of rock sometimes contain gold, distributed through them as pure particles or combined with other elements. Most of the world's gold now comes from reefs of ore, sandwiched in between valueless rock. The working of reefs requires the sinking of shafts and the use of expensive machinery for winning and treating the ore, and is beyond the means of the "small" man.

The most famous gold-bearing reefs of the world are those of the Witwatersrand, in the Transvaal, South Africa. The Witwatersrand is a low range of hills running east and west. In it one edge of what may be great basin-like strata of gold-bearing ore comes to the surface. The ore consists of quartz pebbles cemented together by silica and iron oxide. The Boer name for it is "banket," a word meaning almond-rock, which it resembles in appearance. Very small particles of gold are distributed evenly through the cement

Two valuable features of the gold-field of the Witwatersrand—or Rand,

as it is called for short—are the reliableness of the reefs, as regards both their position and their gold contents. One can be practically certain of striking the reef at the calculated depth, and of getting a profitable amount of gold out of it.

The reefs slope upwards steeply. In opening a mine, shafts are sunk to and through a reef, and then carried through the stratum underneath it, parallel to the reef. At different levels, about 150 feet apart, short tunnels, called cross-cuts, are driven into the reef, and horizontal drives or galleries made from these along the reef, in the ore. The galleries are connected by holes, named winzes, excavated up and down in the vein. So that eventually the ore is divided by galleries and winzes into "stopes" or blocks.

Now begins the stoping, which is the removal of these blocks of ore. The most usual method is to work downwards from one gallery to another, the ore being blasted away in great steps and shot down the winzes into trucks in the gallery below, which carry it off to the shaft. When a stope has been cleared, it is filled in with rubbish, a great deal of which is removed with the ore

Extracting Gold from Ore

In what is called "overhand" stoping the miners work upwards, attacking the roof from a sloping bank of rubbish which they build up as they rise.

South African Railways

POURING OUT LIQUID GOLD

Poets and writers have sometimes likened a beautiful colour in their songs and stories to liquid gold, but the workman in this picture is more concerned with the task in hand than anything imaginary. For the molten stream he is pouring is, in truth, worth a small fortune The photograph was taken at a gold-mine on the South African Rand.

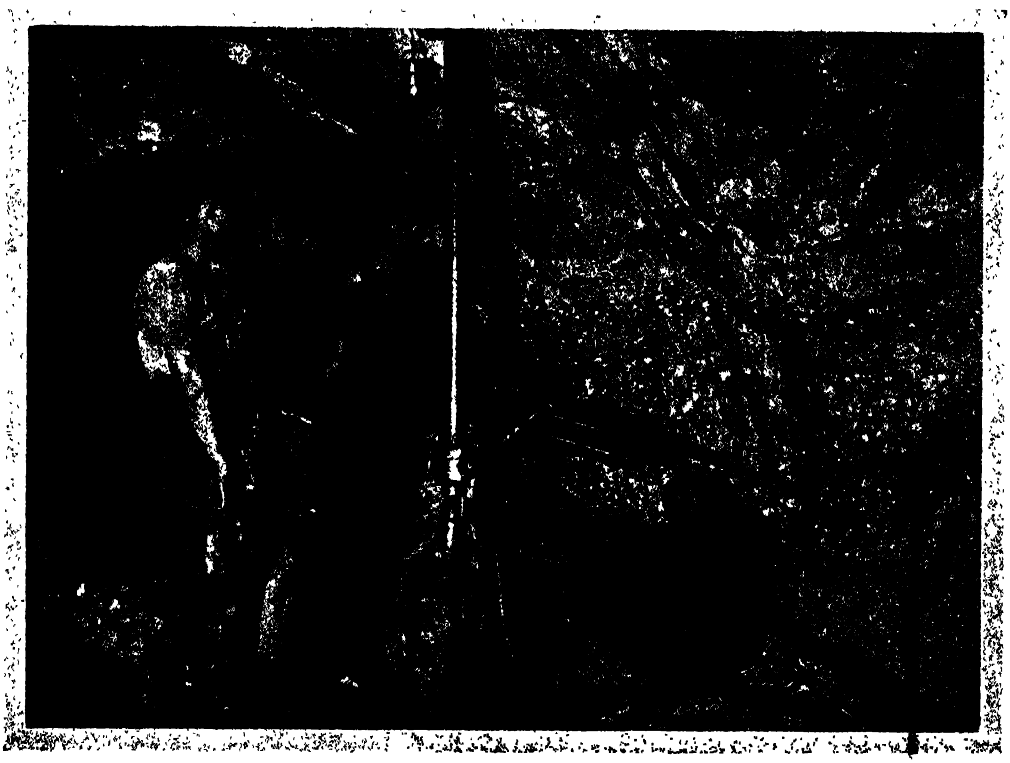
The ore is broken up, after being carefully picked by hand, into a fine powder by stamps. The stamps are, in effect, great iron pestles and mortars. The pestles weigh about a ton each and are raised and dropped ninety times a minute by machinery.

Gathered by Mercury

After grinding, the pulp is passed over copper plates coated with mercury. The mercury absorbs a good deal of the gold. The material that has been over the plates is "concentrated" to remove as much useless stuff as possible, and then placed in great vats containing a solution of potassium cyanide. The potassium combines with the gold. When the solution has been run off, zinc is added. The potassium now dissolves the zinc and leaves the gold deposit itself at the bottom of the vat.

Mining began on the Rand in 1887. Since that year the mines have yielded gold to the value of over £1,657,660,554. They still produce about half of the world's gold yearly supply. If to their output be added that of other gold mines in the British Empire, it will be found that two-thirds of all gold now mined comes from lands under the British flag.

Down to the year when the War of 1914–18 began, people in this country used sovereigns and half-sovereigns made of gold, usually carried on the person in special purses or receptacles. Now, instead of gold coins, we depend on Bank of England notes and find them perfectly satisfactory.



Transvaal Chamber of Mines.

DOWN A DEEP GOLD MINE

Gold-mining in some of its aspects is not unlike coal-mining. Two important features of the great mines on the South African Rand (the short name for Witwatersrand) are the reliability of both the position of the gold-bearing reefs and their actual gold content. Our picture shows miners engaged in drilling in one of the gold-bearing stopes at Modder Deep Levels some 8,000 feet below ground.

BEATING OUT GOLD LEAF

Photos by courtesy of Messrs. George M. Whiley Ltd.

ONE OF THE OLDEST OF THE ANCIENT ARTS

Here we have a general scene in the workshop of the gold beaters of to-day, where a craft which has been exercised by skilled workers for forty centuries is still carried on. Though modern machinery has come to his aid, the gold-beater of to-day requires the same high skill as his forerunners, and English gold leaf now stands at the head of the world's markets.

FROM the days of the ancient Egyptians gold leaf has been in demand because of its durability and brilliance. In the tombs at Thebes wooden coffins were found profusely ornamented with gold, while samples of beaten leaf, ready for application, were found in the tomb of Tutankhamen.

So for forty centuries this craft, one of the world's oldest industries, has continued. In Britain the gold-beater's craft has long maintained its high traditions, and from all over the world come demands for their products. Among the public buildings in England with exterior adornment of pure fine gold (i.e., without addition of any alloy) may be mentioned the Houses of Parliament, the National Gallery, Buckingham Palace and the Victoria Memorial, Windsor Castle, Tower Bridge, while the crowning glory of St. Paul's is the gold cross "that shines over city and river."

Among articles of everyday use ornamented with the gold-beater's aid are shoes and hats, with the maker's name inside; pencils, typewriter covers, spectacle cases, combs and clocks, cricket balls, tennis rackets, bicycles, motor-cars and railway coaches, while bookbinders, artists, makers of picture frames and furniture, as well as dental surgeons and others, all use the product of the gold-beater's craft.

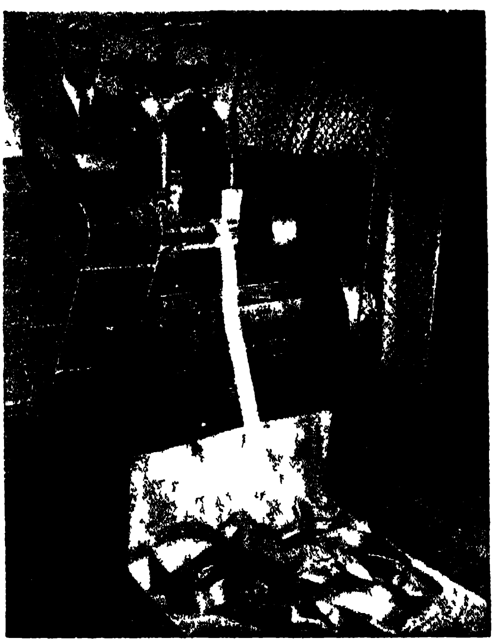
Stages of Production

In a modern gold-beating factory, such as the one of George M. Whiley Ltd., at Ruislip, the processes of gold beating are similar to those of the past, but modern machines have also been introduced. The production of gold leaf at Ruislip is now mostly by means

FROM BARS TO RIBBONS

The fine gold (24 carats) is melted 60 ounces at a time mixed with small quantities of copper or silver as an alloy according to the colour required in the finished leaf

After being melted in a plumbago crucible the gold is cast into bars measuring 11 inches long, 1½ inches wide, and ¼ inch thick One of these bars is seen here



Each bar is then passed many times between highly polished steel rollers, and, with steadily mounting pressure, a ribbon eventually emerges 330 feet long and 1/1000th inch thick

From this long ribbon squares of 1½ inches are cut, these are then filled or interleaved into a "cutch" consisting of specially-prepared 4-inch square pieces of paper

WITH CARE AND SKILL

Gold beaters skins require careful cleaning and pressing after being used and in this photograph the skins are being lightly rubbed with an Arctic hare's foot dipped in calcined gypsum

Some 1,100 gold beaters skins $5\frac{1}{4}$ inches square, form a mould and the delicate quarters of gold are lifted most carefully with foot long boxwood pincers and filled into the mould

In the mould the gold leaves receive the third and most vital beating The skill of the gold beater is concentrated for $3\frac{1}{2}$ hours on transferring the thickness of the leaf outwards

The leaves are taken from the mould with pincers cut with a waggon of sharpened slips of cane to $3\frac{1}{4}$ inches square and then placed in books of twenty five leaves each

of machines capable of making a leaf to that of the highest standards.

The raw material, that is "fine" gold, or gold of 24 carats, is melted 60 ounces at a time, mixed with small quantities of copper or silver as an alloy, according to the colour required in the finished leaf. This is melted in a plumbago crucible from which bars measuring 11 inches by $1\frac{1}{2}$ inches are cast.

Each bar is then passed many times between highly polished steel rollers, and, with occasional annealing and softening, and with mounting pressure, a ribbon emerges $1\frac{1}{2}$ inches in width, $\frac{1}{1000}$th inch thick, and approximately 330 feet long.

Two hundred and twenty pieces of $1\frac{1}{2}$-inch square cut from the ribbon are filled or interleaved into a "cutch"; this cutch consists of 4-inch square pieces of French paper, manufactured by the French firm of Montgolfier, who made the first practical balloon. These squares are bound together with two bands of parchment. In this cutch the gold receives its first beating for about thirty minutes, during which the original $1\frac{1}{2}$-inch pieces are extended to 4 inches square. The cutch being taken out of its bands, each of the 4-inch pieces of gold is separated from the interleaving sheets of papers and laid out on a cushion of calf skin, then cut with a steel "skewing" knife into quarters.

Between Gold-beaters' Skins

These quarters are now "filled" into 4-inch square skins, made of specially prepared ox intestine, called gold-beater's skins, an operation done by women and demanding absolute accuracy. The 880 pieces now comprise a "shoder" and this is beaten for $1\frac{1}{2}$ hours with a 14-lb. cast-iron hammer on huge marble blocks, with leather aprons attached to catch the "shatts" or particles of gold.

From the shoder the delicate leaves of gold are lifted by means of boxwood pincers and quartered with a sharpened reed. These quarters are now filled into a mould, consisting of 1,100 very fine gold-beaters' skins $5\frac{1}{2}$-inch square, and this time the beating is done with an 8 lb. hammer. This is the most skilled of all the operations as the gold-beater's object is concentrated for three and a quarter hours on transferring some of the thickness outwards to form a thicker edge. At the end a fine remainder, as it were, has been beaten out to an even degree of thickness. When this final stage of perfection has been reached the leaves are approximately $4\frac{3}{4}$ inches square.

An Arctic Hare's Foot

The next stage again depends on the skill of women workers, who take the leaf from the skins of the mould with their boxwood pincers, and then, with a "waggon" of sharpened slips of rattan cane (normally set in a square-shaped frame of $3\frac{1}{4}$-inch sides) cut off the thick edges from the leaf. The square leaves of gold are now standard size, $3\frac{1}{4}$ inch square, and are picked up and placed in books of twenty-five leaves each, in which the final product is sold. These tissue paper leaves must be acid free and coated with red ochre—"rouge"—to prevent adhesion of the gold.

The cleaning of the skins after the gold has been removed is also a highly skilled task, carried out with an Arctic hare's foot dipped in calcined gypsum ("brime") Both the powder (from Derbyshire) and the hare's foot are essential to the gold-beater. After cleaning, the skins are dried in hot presses. At no stage is the metal touched by hand. The texture of the gold leaves can only be indicated in figures as about $\frac{1}{250,000}$th of an inch in thickness.

Machines are taking the place of the gold-beater to some extent, but the delicacy and skill of the old craftsmen is to-day being merged with the newer skills of the engineers and technicians, and the ancient craft, reinforced by modern science, goes on unchanging.

SILVER, THE QUEEN OF METALS

High Commissioner for Canada

TAPPING A SILVERY STREAM

The process being watched with so much interest is the making of silver ingots or bullion. The shining, liquid metal is flowing white-hot from the crucible into a ladle, from which it will be transferred like freshly-made jam to the moulds on the left. The great silver mines of Canada were discovered quite by accident.

ONE day, in the year 1573, three long trains of laden mules were threading a forest path in the Isthmus of Panama. The harness bells jangled merrily as the mules plodded along, urged by their drivers and guarded by a few soldiers. The presence of the last showed that the burdens were of value. In a short time the convoy would be taking a well-earned rest behind the protecting walls of a little town a few miles ahead of it.

Suddenly piercing cries arose, mingled with British cheers. Out of the woods flanking both sides of the path rushed Indians and British sailors. Bullets and arrows flew thickly, and the Spanish soldiers, taken completely by surprise, discharged their pieces wildly and fled for the city, leaving the mules and their loads in the hands of the enemy.

Francis Drake, the scourge of the Spaniards, had scored again. In a few moments he and his men had become possessed of 30 tons of silver, then worth well over £200,000. By the time that Spanish reinforcements reached the scene of the encounter Drake's men were well on their way to their ships, lying off the Atlantic shore, with half the spoil, after having hidden the remainder for future recovery.

The Conquest of Mexico

Fifty years before this adventure took place Hernando Cortes and his gallant band of Spaniards had conquered Mexico. The year 1533 saw the conquest of Peru by his fellow-countryman, Francisco Pizarro. The Spaniards came to the New World in search of El Dorado—the fabled Land of Gold. Their conquests did indeed yield them great quantities of the precious metal, which had been gathered into the hands

of the rulers of Mexico and Peru. Millions of pounds' worth of it was shipped to Spain.

But what soon afterwards made Spain the richest country in Europe was the discovery of fabulously-rich silver veins in the conquered lands. The wretched natives were driven by their new masters to toil in the mines and honeycomb hillsides in search of ore. When the German traveller Humboldt visited Mexico in 1800 he reckoned that the Spaniards and their successors had taken £130,000,000 worth of silver from the mines of that country.

During the last 100 years the total has been increased six times or more, thanks to improvements in machinery and methods. If it were possible to gather together all the Mexican silver raised since Cortes' time, it would probably suffice to make a solid pillar 10 feet square and higher than Ben Nevis.

Caves of Aladdin

Many wonderful stories can be told of Mexican silver-mines. At Arazuma huge nuggets of practically pure metal were won from the ground. The largest of them weighed well over a ton! Chance discoveries of veins have led to huge fortunes.

The splendid cathedral at Chihuahua was built with the money realised from one-fortieth of the silver output of the Santa Eulalia mine, in Sonora. A poor priest bought for a "mere song" a claim that had been abandoned as worthless. He soon struck a vein which brought him £600,000. Not far away a wandering fiddler found a button of molten silver in the ashes of his camp fire, and became a millionaire. One could extend the list of such happenings greatly; but let it suffice to say that Mexico is still the chief silver-producing country of the world.

The United States hold the second place. Marvellous finds of rich silver ore have been made in Nevada and Colorado. In 1859 two men prospecting for gold on the western slopes of the Sierra Nevada found traces of the metal in a crumbling black rock. The rock was thrown aside as useless. One day a passer-by picked up a piece of it and sent it to an assayer. It proved to contain £600 silver and £175 gold to the ton.

Then followed a great "rush" to the Comstock Lode, as the vein was named after its discoverer. Fortunate people piled up fortunes until, as generally happens sooner or later in mining, the vein showed signs of exhaustion. During the severe "slump" that came presently, four miners bought up a number of apparently worked-out mines in the hope that they might still contain something of value. Their search for ore had consumed almost all their money when they met with a vein hardly thicker than a ribbon. This they pursued like hounds on a hot scent, till at last it widened out into the greatest body of silver ore ever yet found. For three years silver was taken out of it at the rate of £600,000 a month!

During the present century great silver-mines have been opened in Ontario, Canada. The veins first came to light quite accidentally, while a cutting was being made for the Temiskaming and North Ontario Railway. So rich did they prove that Canada now stands fourth in the list of silver-producing countries. On the average, thirteen ounces of every pound of silver mined to-day comes from the New World. About 7,000 tons of silver is smelted from ore every year.

How Silver is Separated

Silver is very seldom found in a pure state. Most of it comes from ores in which it is combined with sulphur or chlorine. It also forms part of many lead and copper ores. The silver is separated from the less valuable or worthless parts of an ore by one of several different processes.

In some cases the ore is ground into powder and mixed with mercury, which seizes on the silver particles and forms

DRAKE AND THE SPANIARDS

Specially drawn for this work

Sir Francis Drake, romantically known in history as the scourge of the Spaniards, once in a forest path in the Isthmus of Panama attacked a convoy and its guard of soldiers and succeeded in capturing some 30 tons of silver, valued in this great admiral's day at upwards of £200,000. The encounter between Drake's sea-rovers and the Spaniards is illustrated in this spirited drawing.

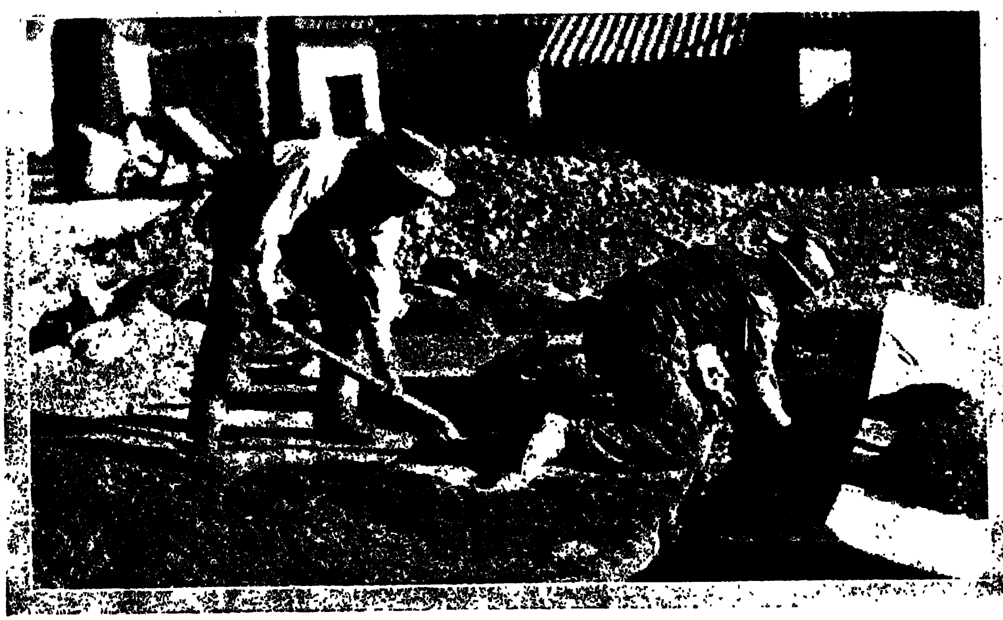
SOME STAGES IN THE PROCESS OF—

When the silver ore has been won from the mine it is in the form of large rubble, which has to be crushed almost into dust The old-time method of crushing is still in use, and consists of rolling a massive boulder over the ore till a sandy deposit remains

Photos G P A

This dusty, sandy matter must then be put into a pond or "buddle," about 5 feet in depth, where it is thoroughly mixed with the water by means of the rotating wheel in the centre In this manner a kind of sticky mud is formed

When the mud-like ore is taken from the buddle it is placed in a square box, the bottom of which is a fine screen, like that of a cinder sieve. This box is then submerged in a trough containing water and the process causes the heavy silver dust to settle at the bottom of the trough and it can then be easily collected.



Photos: G.P.A.

Having emerged from one complete washing the ore that has passed through the meshes of the sieve is removed from the trough and placed this time into running water. In this stage of the treatment the heavy metal settles at the bottom of the water and such dirt as remains is washed away. The workers at the mine here illustrated are mostly negroes.

a paste, called an amalgam. The amalgam is heated in iron retorts, and the mercury boils and passes off as vapour, which is condensed back into the liquid state, while the silver remains behind. In other cases chemicals are used to dissolve the silver, or it is extracted by heating in a furnace.

If gold be the king of metals, silver is the queen of them Silver is rendered beautiful by its pure white colour and by its great brilliancy when polished Though it is now much less valuable relatively to gold than it was once, its price at the present time being very much lower than that of gold in the market, it is still sufficiently rare, as compared with most other metals, to be used in great quantities for coinage, ornamental goods, dishes, forks, spoons, and other articles. We still speak of the children of wealthy parents as "born with a silver spoon in the mouth."

C P A

CRUDE SILVER IN ITS "JELLY-BAG"

The cheerful-looking young man here smiling at us has gathered up crude silver after the second washing and is taking it in a bag of curious shape to the smelting departments for the next step in the sequence of operations

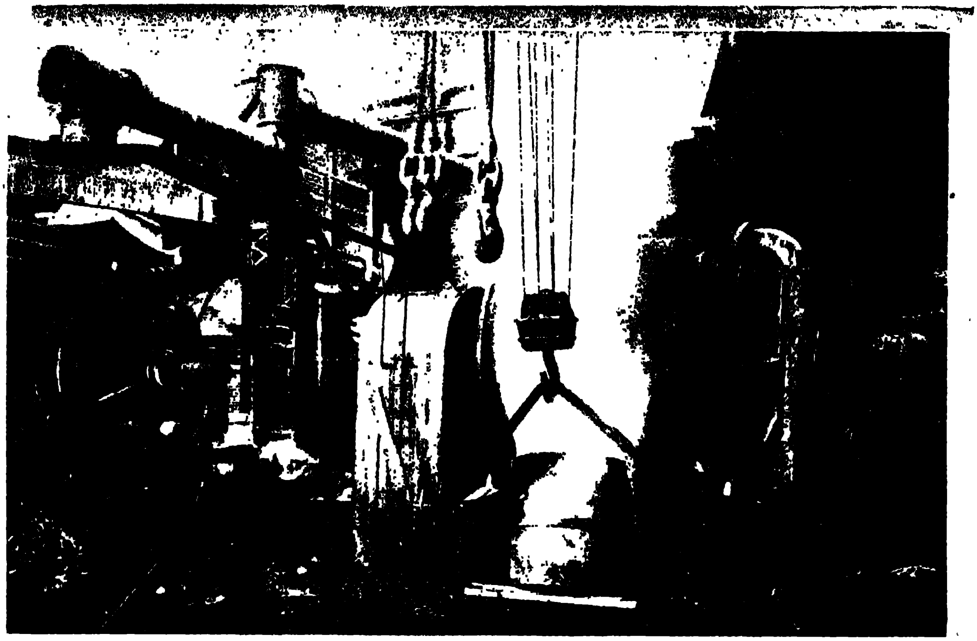
Where solid silver would be too expensive, plated goods are used instead, a baser metal being hidden under a gleaming skin of pure silver.

Key of the Camera

If you look into a mirror, your image is reflected by a film of silver deposited on the back of the glass. The pictures which you watch on the screen of a cinema have a connection with silver-mines, for every photograph taken with a camera makes use of a compound of silver that is affected by light if exposed to it for even a tiny fraction of a second

Again, silver salts generally are present in the films on to which photographic pictures are printed. It would be possible, though very difficult, to take photographs without the aid of silver, but it would be very slow work, and anything in the nature of snap-shotting would be quite out of the question

NICKEL, THE GOBLIN METAL



Keystone View Co.

A CONVERTER DISCHARGING COPPER

Canadian nickel ores contain copper, which has to be separated from the nickel. In one process this is effected by heat. The copper then has most of its impurities removed by air blown through it in a "converter," which is here seen discharging the copper into a casting ladle

IN the year 1907 engineers were hard at work constructing a great railway bridge across the St Lawrence River at Quebec. Good progress was being made when, on August 29th, half the structure collapsed and crashed into the river, killing a large number of workmen. Apart from the loss of life, it was a terrible disaster. In a few moments over 15,000 tons of steel-work became a tangled mass.

Steel and its Ally

The whole of the bridge was removed and a new one designed. This was completed successfully in 1917. The engineers responsible for it determined to run no risks a second time, so they used a specially strong steel, called nickel steel, containing a few parts in a hundred of the metal named nickel Nickel is a weaker material than steel, yet when added to mild steel it increases its strength greatly.

We may put the facts in this way . Take two bars of the same size, one of ordinary steel and the other of nickel steel. If the first can stand a stress of 100 tons, the second will be able to bear a stress of from 130 tons to 180 tons, according to the amount of nickel in it. Why the addition of nickel should bring about this extra toughness is very mysterious. But we find the same kind of thing in other alloys of metals. Why, for example, should weak aluminium become as strong as steel, though only one-third of its weight, when it is mixed with a little copper and magnesium ?

On account of its great toughness, nickel steel is used for many purposes. If you had before you a description of the many parts of a locomotive, you would probably see that the driving axles, crank pins, piston rods, connecting rods and coupling rods are made of this metal. It can be relied upon not

to crack under great strains. And those very important parts of a motor car's engine, the valves, are usually of nickel steel, because the nickel enables the steel to stand great heat without being burned away

Experimenters discovered some years ago that nickel steel containing thirty-six parts of nickel out of 100 has the very remarkable quality of not changing its size with ordinary changes of temperature. You have been told that the rails of a railway track must have gaps left between their ends to allow for expansion in hot weather If one could afford to make them of this changeless steel, gaps would be unnecessary, and trains would run more smoothly. This kind of steel has been named ***invar***, on account of its dimensions being practically invariable at all air heats.

For what purpose should invar be particularly well suited? This is a difficult question for you to answer, so we will say at once that invar is the ideal material for the measuring-tapes used by surveyors, and for standards of length The length of a 66-foot steel tape is correct only at a certain temperature, and in making very accurate measurements one must allow for this. On a blazing hot day it will be too long, and on a freezing winter's day too short. But the changes in an invar tape are too small to be worth worrying about

Mond Nickel Co, Ltd

AT THE PIT-HEAD

The pit-head of the Mond Nickel Mine at Frood, Ontario The tallest part of the structure stands over a shaft 3,000 feet deep Ore broken below ground into large lumps is hoisted to the top of the headworks, and passed down through crushing machines into storage bins, from which it falls into trucks

A Triple Alliance of Metals

If a third metal, chromium, be added to nickel and steel, we get nickel-chrome steel You have made the acquaintance of one form of it in the "stainless" dinner knives that have become so popular, and with good reason, as they are not stained by vinegar and can be kept bright and clean without the tedious labour of rubbing them on a knife-board. Very possibly the blades of your pocket-knife are forged from the same metal

THE LAST STAGE IN REFINING NICKEL

Mond Nickel Co., Ltd.

The tower-like objects seen here are called decomposers. Each contains a charge of nickel pellets, which are constantly being lifted to the top and allowed to fall again. Nickel, combined with carbon monoxide to form a gas named nickel carbonyl, is passed through the decomposers. When great heat is introduced the gas breaks up. The nickel is deposited on the pellets, and the monoxide is drawn off.

Nickel-chrome steel finds grimmer uses in the armour-plates of warships and the projectiles for piercing the same. When a nickel-chrome steel shell fired from a big gun strikes a nickel-chrome steel plate, it is indeed a case of Greek meeting Greek !

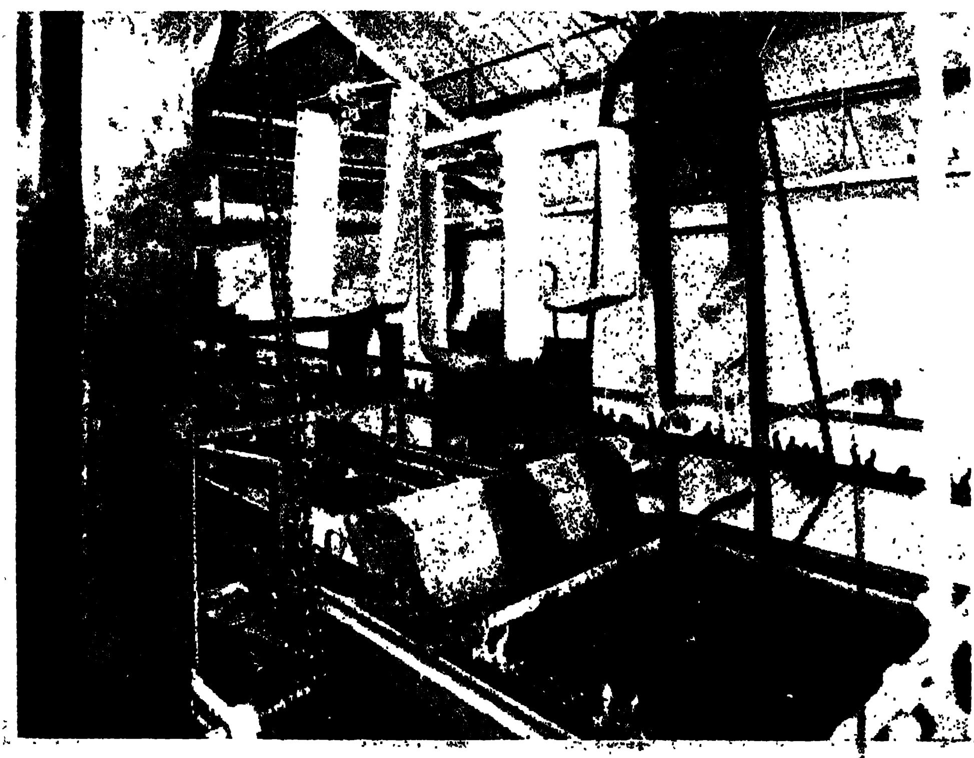
The mention of armour and shells reminds us indirectly of the use of nickel for coinage. Low-value coins of pure nickel, or of nickel and copper mixed, are used in many foreign countries and in some parts of the British Empire. There are probably in circulation some thousands of millions of these coins.

During the War of 1914–18, Austria-Hungary, Germany and Turkey called in all their pure nickel coins and melted them down for war material. These countries were cut off from all outside supplies of the metal, so they made use of their great reserve of it in the form of coins.

The bright parts of your bicycle are plated with pure nickel. It gives them a smart appearance, besides protecting the steel below from rust. If you take sufficient pride in your machine to polish these parts occasionally, it is rewarded by the sheen of the nickel, which is brightened more easily than silver or brass. For this reason taps and bathroom fittings, and the metal parts of horses' harness, and many items of a motor car are nickel-plated.

How Nickel got its Name

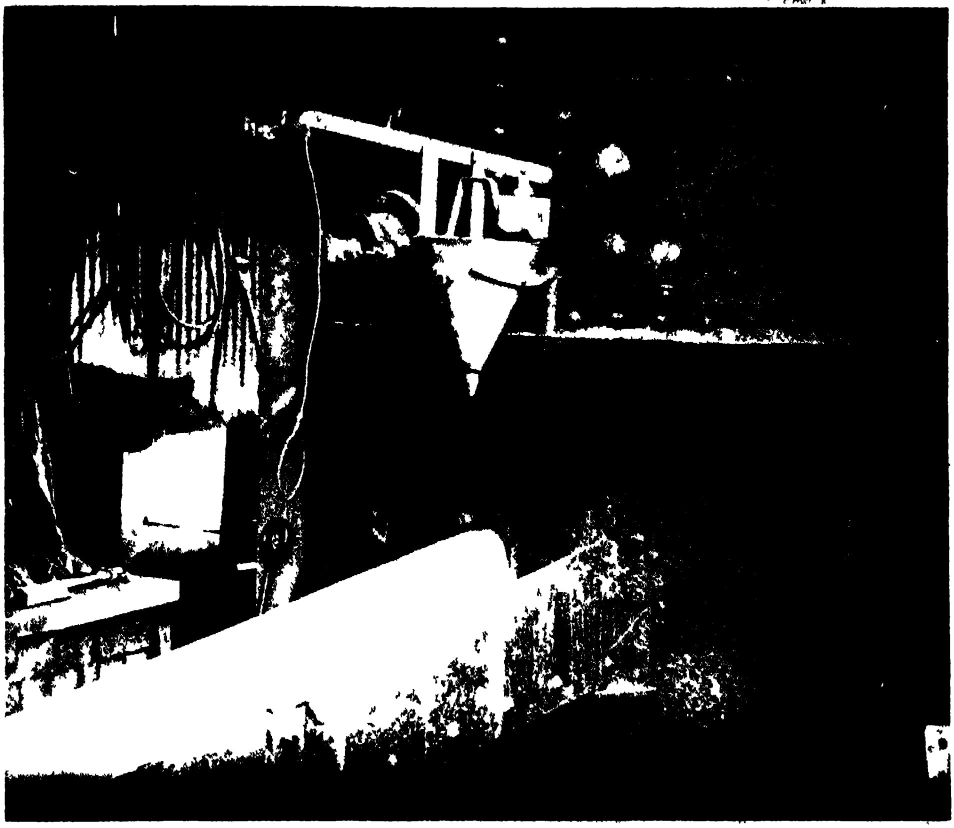
Pure nickel was not produced until about 1805, and is therefore a late-comer among the metals in common use. The origin of its name is rather



Mond Nickel Co., Ltd.

NICKEL-PLATING

Nickel is much used for electro-plating articles to protect them from corrosion and to improve their appearance. In this illustration the covers of motor-car radiators are seen coming out of the nickel-plating vats in the radiator factory at the Morris Motor Works, Oxford.



Mond Nickel Co. Ltd

ADDING NICKEL TO IRON

The addition of nickel to cast iron renders it stronger and easier to shape with tools. As the molten iron is run out through the discharging trough of a cupola, the nickel in the form of pellets is allowed to fall into it from funnel over the trough.

interesting. Some hundreds of years ago the miners of Bohemia found an ore which looked like copper ore. They put it into their smelting furnaces, but no copper came out of it.

Like a Troublesome Imp

In disgust, they dubbed the stuff "nickel," a word which means a hobgoblin or troublesome imp. Many years later a way of extracting metal from the ore was discovered. The new metal received the name originally given to the ore. This was hardly fair, for, as you will have realised by this time, nickel is very useful to us in many ways.

Most of our nickel now comes from the Sudbury district of Ontario, in Canada, where great deposits of nickel copper ore occupy an oval-shaped area measuring about 36 by 30 miles. They were discovered in 1883, during the construction of the Canadian Pacific Railway. Before this find was made the chief source of supply was the island of New Caledonia, lying 1,077 miles north-east of Australia.

Captain Cook discovered the island in 1774, but for eighty years no nation thought it worth annexing. Then the French ran up their flag over it and, as a result, were able to control the price of nickel for a long time. As a matter of fact the first patents in connection with nickel steel were taken out from a French factory.

COPPER—THE RED METAL

International Nickel Company

DRILLING HOLES FOR BLASTING COPPER ORE

Until about 1850 Britain was the world's largest copper producer, but the supply of ore fell rapidly, and no copper is mined in this country to-day. In most cases copper deposits, wherever found, must be reached by some form of mining. The usual method is to drill holes into the ore body and then load with an explosive charge. This article, which has been prepared with the kind assistance of the Copper Development Association, explains the production and many uses of copper

THE only coloured metals, copper and gold, were the first worked by man, and have been in continuous use down the centuries. Of the two, copper is the more abundant and decidedly the more useful metal. Primitive man discovered that a lump of the naturally occurring metal, or native copper as it is called, could be hammered to any required shape and that it became harder and stronger in the process. Thus he was able to replace stone implements and weapons by copper ones. This use of copper probably continued for many centuries before bronze was intentionally made. One of the tombs of the ancient Egyptians, when opened a short time ago, was found to contain a hoard of hundreds of copper tools. Although they were fashioned thousands of years ago, these copper tools were in excellent condition, for copper does not rust and is practically indestructible.

Bronze, which is mostly copper with the addition of a small amount of tin, was discovered later in history, and was found to be harder and stronger than copper. Brass, which is obtained by adding zinc to copper, was known to the Greeks and Romans. Such combinations of metals are called alloys, and copper forms the base of a great many alloys which are widely employed in industry. This is because copper and its alloys are easily worked and become stronger in the process, and have long-lasting qualities. They are also good conductors of heat and of electricity.

A Conductor of Electricity

The astonishing growth of most industries in the past hundred and fifty years has been due largely to the availability of electrical power, and electricity depends on copper. Next to silver, copper is the best conductor of electricity. It was soon discovered that the presence of impurities in amounts so small that they were regarded as of no account, affected

the ability of copper to conduct electricity.

So a great demand arose for high purity, or high conductivity copper. Although large amounts of copper in the native state have been exploited, as in the Lake Superior region of North America, nearly all the copper now produced comes from copper-bearing rocks called copper ores. Such ores are widely distributed throughout the world. They are found in the United States and Canada, Northern Rhodesia, South Africa, Spain, Chile, Australia, Turkey, India and Japan and in parts of Russia.

It is of interest to recall that copper was once mined in Britain, in Cornwall and Anglesey, and that until 1850 this country was the world's largest copper producer. World production of copper to-day averages about 2½ million tons a year, of which nearly a quarter is derived from the British Commonwealth.

Scattered in Grains

Copper ores are found at various depths, from near the surface where they are quarried like stone, to many hundreds of feet below ground level where they are mined like coal. Sometimes the ores occur as layers or veins in the surrounding rocks, but mostly they are scattered as minute grains of copper minerals in large bodies of rock. As a rule, the deposits do not contain more than 1 or 2 per cent. of the metal. That is to say, 100 tons of ore may yield less than 2 tons of copper.

Copper combines readily with sulphur, and its ores are generally sulphides ; either combinations of copper and sulphur, or copper, iron and sulphur, with small amounts of other elements included. Chalcopyrite, a sulphide of copper and iron, is stated to account for one half of the world's total supply of copper. The deposits of this glistening yellow mineral in Spain

Mufulira Copper Mines Ltd

UNDERGROUND HAULAGE IN A COPPER MINE

In many mines coarse jaw crushers are used to reduce the larger lumps of copper ore while still in the mine, after which the ore is loaded into trucks drawn by a locomotive and taken to the bottom of the shaft to be hoisted to the surface. This picture gives a good idea of the underground haulage system in a modern copper mine

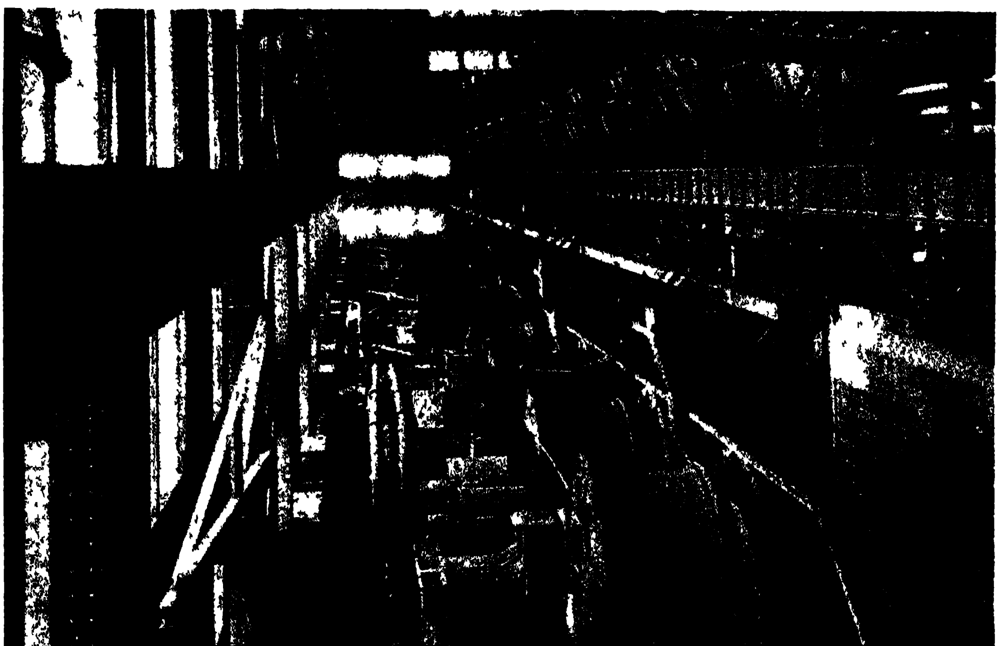
contain so much sulphur, that large amounts of both sulphur and copper have been obtained from it. Bornite, another sulphide ore, is known as "peacock ore" on account of its brilliant colours. Another class of ores, the oxidised or weathered ores, include such minerals as malachite, which is bright green, and azurite, which is blue. Although such minerals may contain anything from 30 to 90 per cent. copper, not one of them occupies much of the ore body, but must be extracted from large masses of useless rock.

Although large deposits of copper ores are found at or near the surface of the earth, as at Utah in the United States and at Rio Tinto in Spain, the vast majority of ores are only reached by deep mining. New deposits are found by drilling boreholes by means of hollow drills. The nature of the different layers of rocks can be told by examining the drillings collected inside the hollow drill as it descends.

Reduced to Fine Powder

When the prospectors have indicated by borehole samples the nature and extent of a promising ore body, mine shafts are sunk to appropriate levels, and from these tunnels are driven into the ore body, with cross-cuts to facilitate the removal of the ore. In this way a vast network of passages is made, connected by sloping ways or "raises." Large storage spaces are also made, and sometimes machinery for rough crushing is installed below ground The main tunnels have light railways or conveyor belts to carry the ore from the inner workings to the mine shafts, whence the ore is raised to the surface

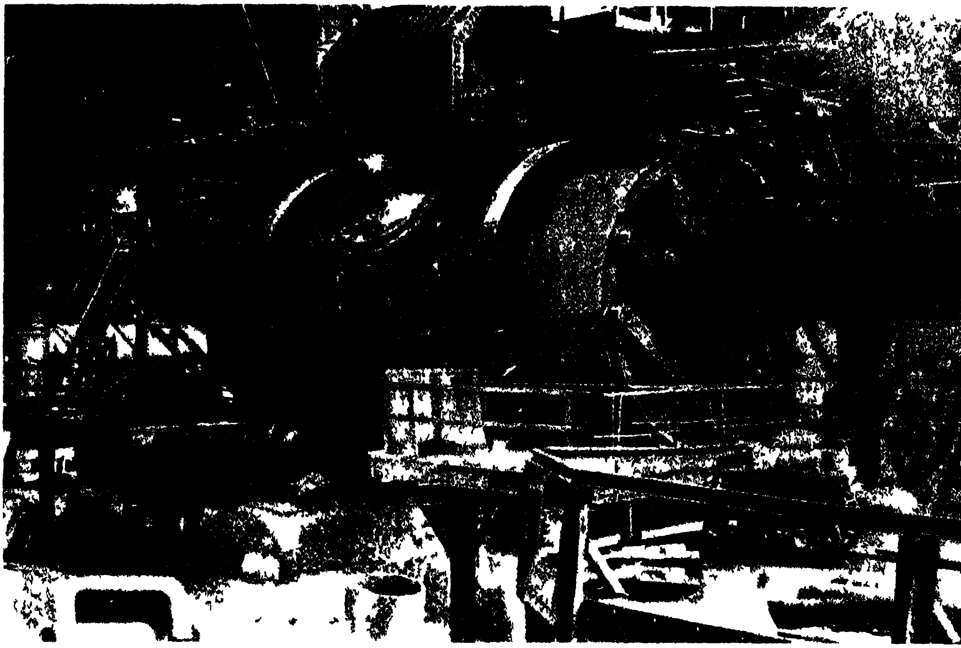
To mine the ore, a chamber is excavated in the ore body and holes are drilled into the walls and roof. Charges



Rhokana Corporation Ltd

GRINDING COPPER ORE IN BALL MILLS

Before the copper ore can be concentrated and taken to the furnaces for smelting it must be crushed and then ground down to powder The grinding is done in rod or ball mills, which are steel containers holding some tons of loose steel balls or rods By their rotating and cascading as the mill revolves these gradually grind the ore to powder



Rhokana Corporation Ltd

HOW THE ORE IS SMELTED

The finely ground ore passes through a series of flotation cells which separate the valuable part, the sulphide grains, from all the worthless matter. After the valuable part, called the concentrate, is dried, thickened, filtered and smelted in a reverberatory furnace, the matte, as it is now known, is charged into a converter. This photograph shows a converter after being charged.

of explosives are rammed into the holes, and by means of long fuses groups of charges are exploded simultaneously, bringing down large masses of ore at a time. The ore obtained in this manner falls down chutes into storage spaces or into trucks. Coarse jaw crushers may reduce the larger lumps of ore before it is hoisted to the surface.

At the top of the mine, the ore is tipped on to an ore dump, from which it is drawn as required. Before it can be melted to extract the copper from it, the ore passes by conveyor belt to a series of crushing machines. Finally, it is mixed with water and fed into large cylinders containing tons of loose steel balls or rods which cascade down on the pieces of ore and grind them to a fine powder. Ore which is still not fine enough is separated by classifiers and returned to the grinding mills. A classifier is an inclined trough with a series of rakes, or a metal spiral, by which the coarser material is pushed over the top and returned to the ball or rod mills. The now finely ground ore in water is allowed to flow to flotation cells, where the copper-rich particles are separated from the worthless rock. In each cell, pine oil is added to the mixture of ore and water, and air is forced up through the mixture, causing it to froth. The copper bearing particles adhere to the froth and overflow the cell, while the useless rock particles sink to the bottom. A single plant may contain hundreds of these cells.

Ready for Smelting

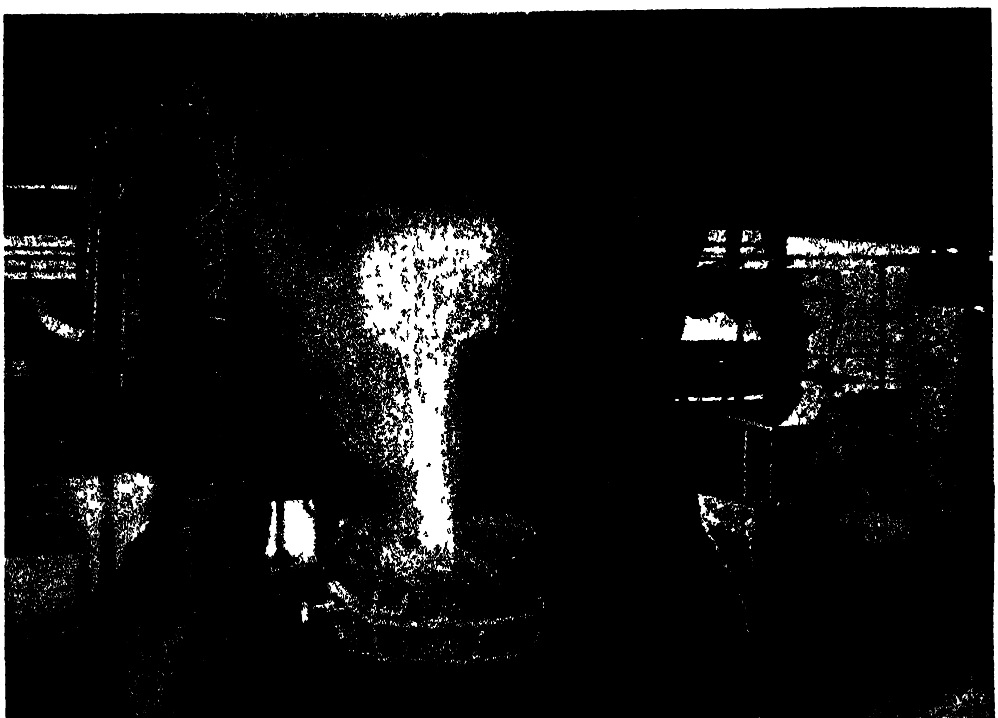
The valuable matter, which is made up of copper and iron sulphides, is called concentrate. It is sent to thickeners, which are large tanks with revolving arms which draw the solid matter to the centre and allow most of the water to drain away. The

remaining water is removed by suction filters. Excess sulphur may be removed from the concentrate at this stage by roasting.

The copper ore is now ready for smelting in a reverberatory furnace, in which the flames from a set of burners at one end pass over heaps of ore and fluxes spread over the hearth. The fluxes form a slag which takes up some of the impurities from the molten ore which is now called matte. The matte is still a mixture of copper and iron sulphides, and while in the molten state it is removed in ladles and charged into converters. In a converter, air is forced through the molten matte and as it combines with the sulphur great heat is generated. The sulphur escapes as a gas, sulphur dioxide, and the iron goes into the slag, leaving crude copper. As the copper is poured into moulds, it bubbles, and the resulting large cakes of copper are known as "blister copper" from their blistered appearance.

Refining by Electrolysis

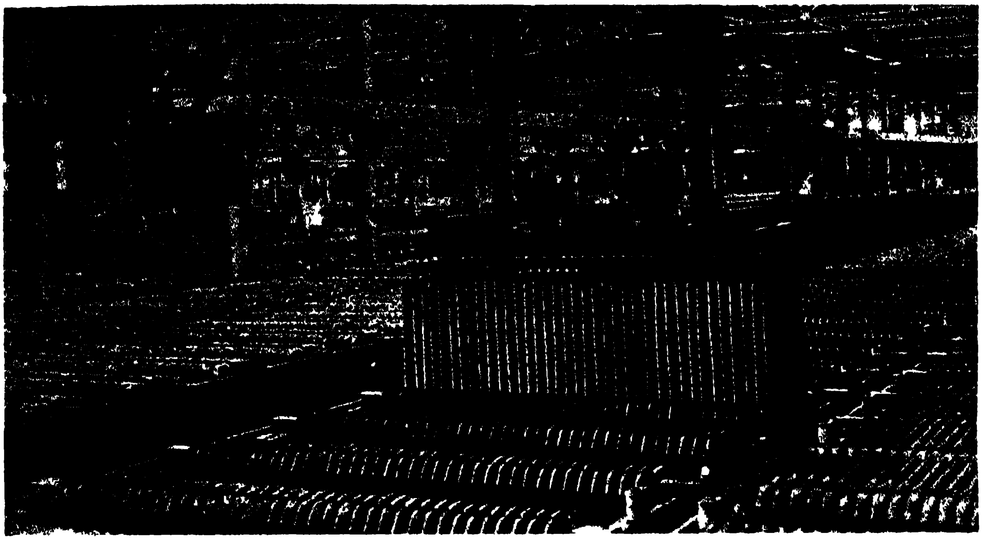
Blister copper is not fit for commercial use as it may still contain small quantities of iron, sulphur, bismuth and other impurities, so it must be refined. The refining is done in another reverberatory furnace where the blister copper is melted. Air is blown through the molten metal to remove the impurities, and the final removal of oxygen is done by inserting long poles of green wood into the metal, a process called "poling." The refined copper is then tapped, the flow of metal being directed to a casting wheel carrying heavy moulds of the required shape to



Rhokana Corporation Ltd

POURING THE MOLTEN COPPER

The copper "matte" is in the converter for about three hours, during which all the iron is oxidised and slagged off, and the remaining sulphur is blown out. The converter is then tilted, as seen in this photograph, and the molten copper poured into ladles and transferred to a heated holding or casting furnace.



International Nickel Company

IN THE ELECTROLYTIC TANK HOUSE

To produce copper of high purity the electrolytic refining process is used whenever necessary. Here we have a view in the Electrolytic Tank House, showing the copper cathodes being removed from the tanks. In this process the insoluble impurities in the copper, including gold, silver, lead and tin, sink to the bottom of the tank to be recovered later.

produce wire bars, billets, cakes or anode plates.

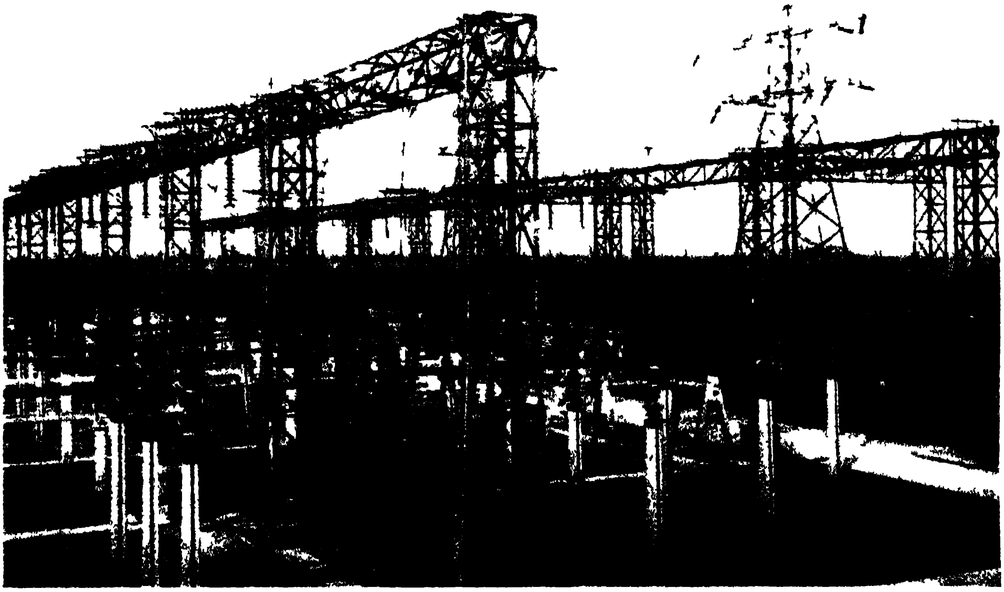
Copper of high purity can be obtained by fire refining, but if further refining is required this is done by electrolysis, using anodes made by fire refining. The anodes have lugs by which they hang in tanks between thin sheets of pure copper called starting sheets. The tanks contain dilute sulphuric acid and dissolved copper sulphate, and when an electric current passes through the tanks, the copper anodes dissolve and the copper passes to the starting sheets which grow in thickness forming cathodes of pure copper. The impurities in the anodes, and any gold, silver or other valuable metals which may have remained in the copper through a the refining stages, settle to the bottom of the tanks as a sludge which is treated separately to recover the precious metals. The copper cathodes are taken to a furnace where they are melted and the refined copper is poured into moulds, to form wire bars, billets or cakes.

Electrolytically refined copper, being of the highest purity, is specially suitable for electrical uses and for making high grade copper alloys.

Copper for the manufacturing industries is supplied as sheet and strip, bars, rods, wire and tubes. Over 180,000 tons of copper wire is made every year in Britain alone, to provide cables for electricity supply, telephones and telegraphs, submarine cables, and special cables for radio and television transmission. Copper sheet is widely employed as roofing for buildings, large and small, and for many kinds of chemical and other plant. Tubes of copper and copper alloys are also used in buildings for water, gas and sanitation services, and in many industries. Heavy copper tubes are employed as engraved rollers for printing.

The addition of other metals to copper produces a wide variety of copper alloys which are important in many industries. Mention has already been made of bronze, an alloy of copper and tin, and brass, an alloy of copper and zinc. These have many applications as castings, stampings and pressings, as well as in wire and tube forms

FOR POWER AND PROTECTION



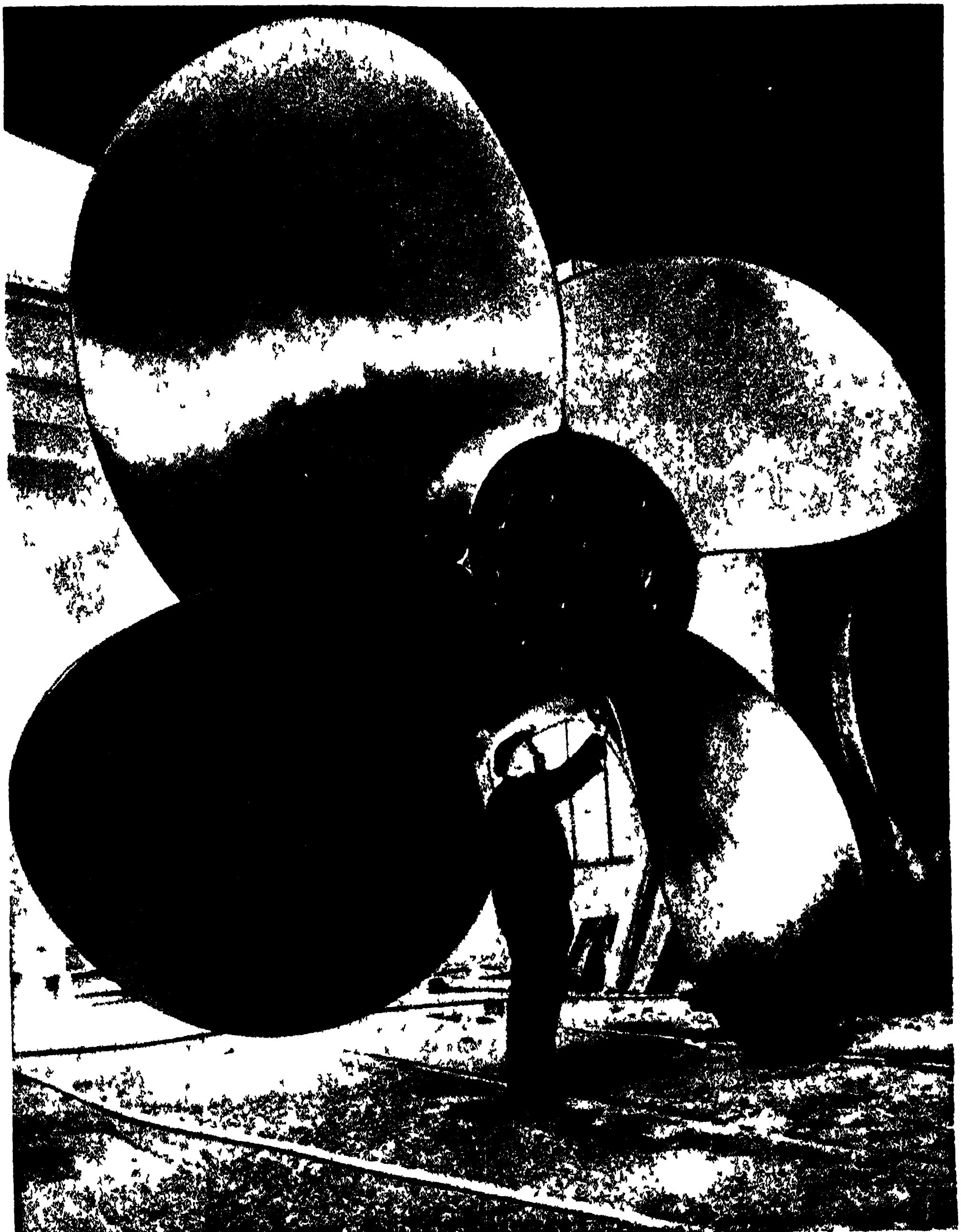
British Electricity Authority

The electrical industry is largely dependent upon copper particularly in the form of wire because the electrical conductivity of copper is greater than that of any other metal except silver Actually more than half of all the copper produced is now used in the electrical industry, and this photograph gives some indication of the miles of copper wire used in the transmission of electric power

Copper Development Association

In Roman times copper was used as a roofing material Remains of this, after the passage of hundreds of years, were removed and again put to good use The dome of the British Museum is roofed with copper, and so are the domes on the Old Bailey and the Bank of England, among other London buildings Our photograph shows the copper roofing on Liverpool Cathedral

A GREAT LINER'S PROPELLER



J Stone & Co., Ltd.

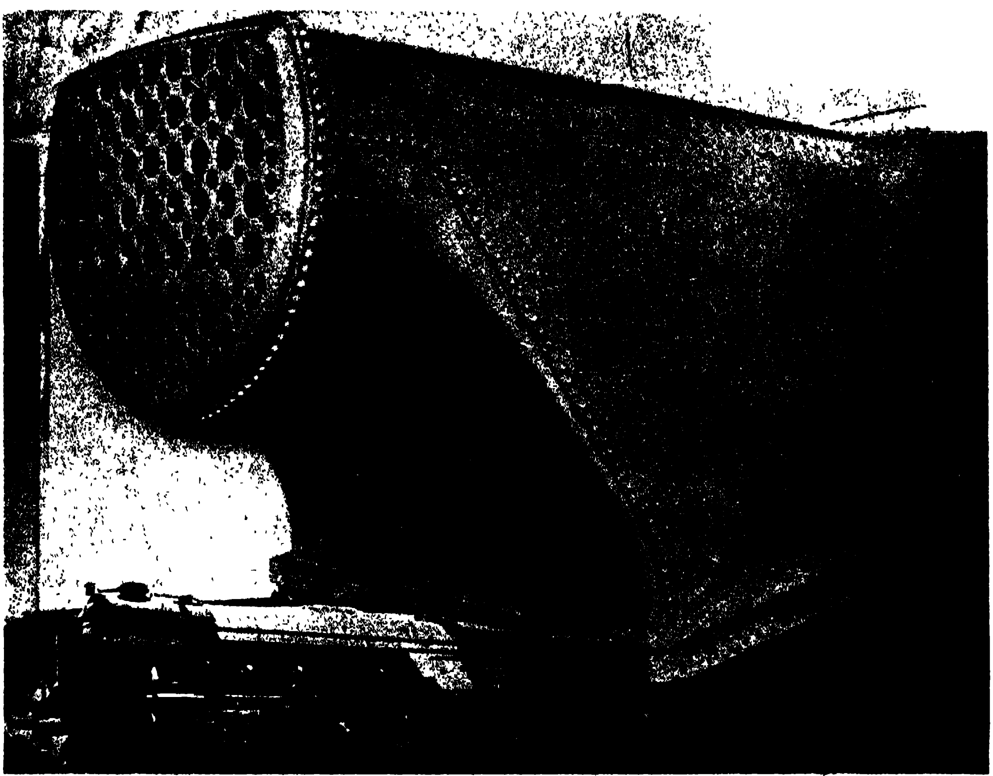
In the shipbuilding industry copper and its alloys are used extensively Here we see one of the four great propellers of the *Queen Elizabeth* These propellers are made of high tensile brass, and each of them weighs over 30 tons Brass one of the best-known of the hundreds of copper alloys used in industry to-day, contains at least three fifths copper, the remainder being mainly zinc.

Copper nickel alloys, familiar to us as coins, are highly resistant to corrosion and for that reason are employed in making chemical plant and for condenser tubes. Another copper alloy which does not corrode, aluminium bronze, has many industrial uses and has such an attractive appearance that it has been used for powder compacts and inexpensive jewellery. Nickel silver is a copper alloy which contains nickel and zinc but no silver, although it gets its name from its silvery appearance. Besides making handsome tableware it is produced in large quantities for electrical purposes. Cadmium copper is specially suited for trolley wires as it stands up to rough usage.

The list of copper alloys is almost unending, and includes special alloys such as tellurium copper, beryllium copper, chromium copper, and many others, each having its own combination of desirable properties while retaining for the most part the qualities which make copper itself a material so essential to modern civilization.

It is not only as a metal that copper is of great value in modern life. Copper chemicals are sprayed on potato and other plants to protect them from pests and diseases. Copper is a constituent of some anti-fouling paints used to protect ships' bottoms against marine growths. Copper is used to make coloured glass, in metallic printing inks, and for hundreds of other purposes.

One may safely say that there is scarcely an industry in which copper is not used in one form or another, and that it is as essential to-day as it has been all through its long history.



Copper Development Association.

A LOCOMOTIVE COPPER PLATE FIREBOX

In this photograph is seen a new locomotive firebox, made of heavy copper plate, and on a smaller scale is inset a modern locomotive in which, besides the firebox, many fittings are made of copper or of one of its alloys, such as brass.

ZINC, THE GALVANISING METAL

Photos by courtesy of Imperial Smelting Corporation Ltd

CHARGING THE RETORTS WITH BRIQUETTES

The most modern method of extracting zinc from its ore is by pyro-metallurgy (extracting by heat) by the American Vertical Retort process, and in this photograph the vertical retorts are seen while being charged with coked briquettes.

THERE are a number of ores from which zinc is extracted, but only two can be considered of importance, blende, the sulphide of zinc, and calamine, the carbonate. Blende is the more abundant and therefore the principal source to-day.

Unlike many metals which are mined, zinc does not occur on its own, but it is associated with the ores of lead, silver, copper and sometimes tin, often forming extensive deposits of a very complex nature.

Extraction of Zinc

There are two main principles in operation for the extraction of zinc from its ore :

(1) Pyro-metallurgy, or extraction by heat.
(2) Electrolytic, or extraction from a solution of zinc salts by an electric current.

The most modern method of zinc extraction by pyro-metallurgy is the American Vertical Retort process. There are three such plants in America, one in Germany and one in England, at Avonmouth, near Bristol.

Applications of Zinc

Though one of the most important metals in everyday use, zinc often passes unrecognised and thus is not treated with the respect it so richly deserves.

Brass, that ubiquitous metal, is an alloy of copper and zinc ; it is manufactured in the form of sheets, tubes, rods and wire, castings and forgings ; it is used for making anything from brass buttons to the propellers of R M.S. *Queen Mary*.

Think of the number of items which one sees daily that are galvanised. A galvanised article is one of iron or steel which is fabricated and afterwards dipped into a bath of molten zinc. The reason for galvanising is that zinc will not rust, and when enveloped the iron and steel are efficiently protected from rusting. A galvanised article will with-

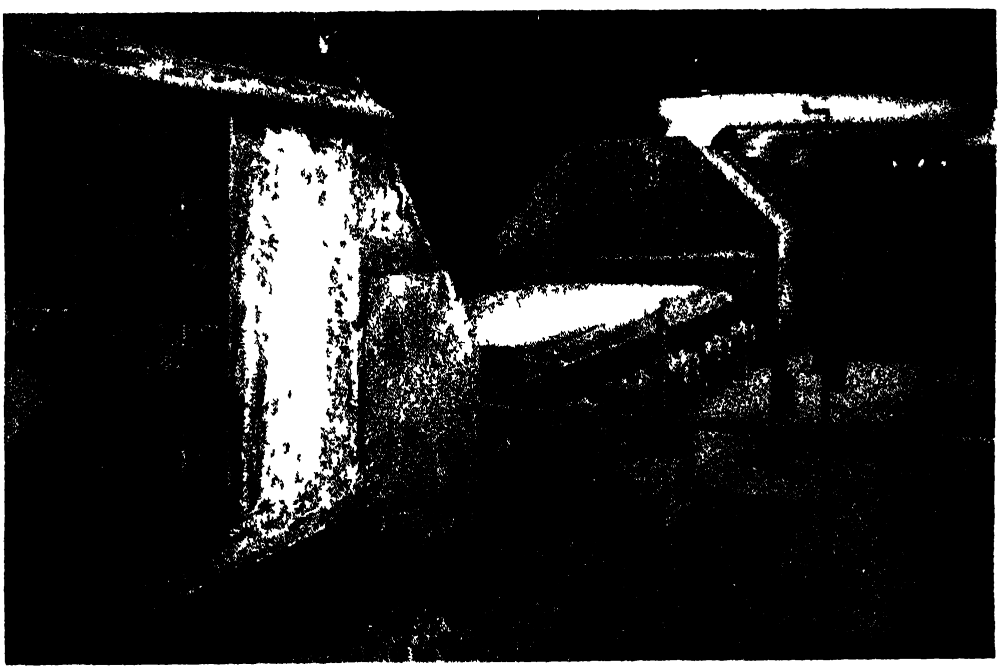
stand the rain and damp atmosphere for many, many years

To quote but a few examples which will indicate the wide sphere of usage to ensure a long and perfectly safe life the pylons which carry electrical current across the countryside are galvanised. The farmer enjoys longevity of much of his equipment by knowing it is protected from rust his buckets, food stock bins, feeding troughs barbed wire and even the roofs of his barns. At home many examples can be found, such items as buckets and watering cans are galvanised, and most likely the steel window-frames of the house before they are coated with paint

Though galvanising is the most used method of coating with zinc, there are other methods which have their own particular applications, such as when a bridge is to receive the protection of zinc. This is far too large to be galvanised, it is therefore sprayed with zinc. Small objects such as screws and nails are sherardised, this entails the objects being placed in a container in which there is a quantity of zinc powder. The container is sealed and slowly revolved in a furnace. The zinc impregnates the surface of the iron, forming an inner iron-zinc alloy merging into a zinc-iron alloy, and finally, on the surface pure zinc

Another method of coating articles with zinc is by plating, this method is limited to components of such size that they can be disposed conveniently in a plating tank. Electro deposited zinc coatings find wide application for protecting from rust many articles fabricated from sheet steel. They are also employed on wire and on nuts and bolts and similar small components

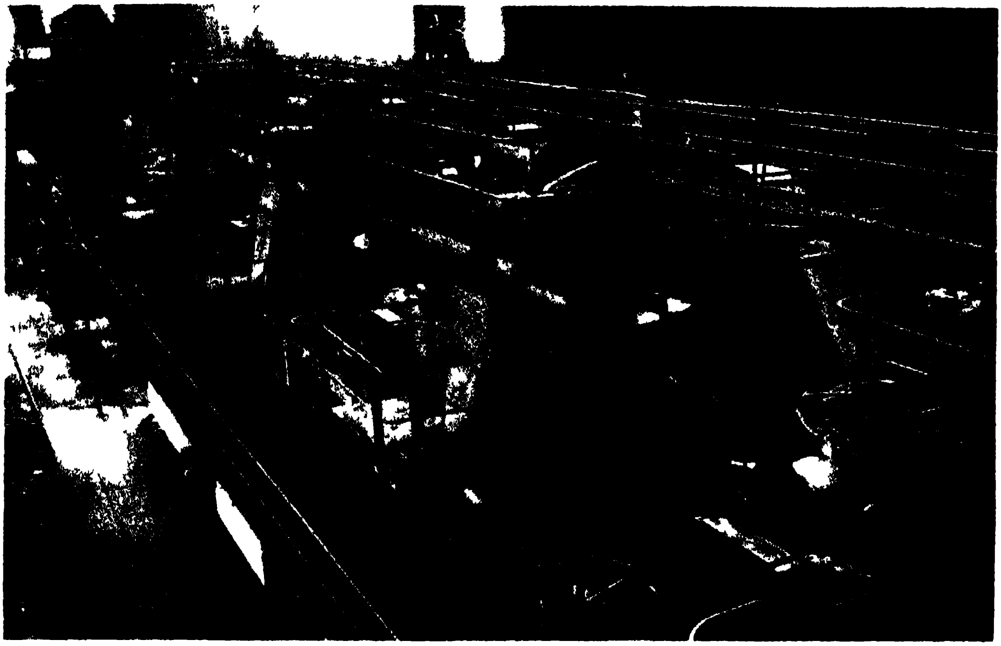
Rolled zinc, which is made by rolling slabs of zinc into sheets is used extensively in the building industry for roofing gutterings and waste pipes. Large quantities are used for the cases of dry electric batteries owing to its special electro chemical properties. Printers use sheet zinc for their litho-



ROASTING THE ZINC ORE

This photograph shows the sintering machines which roast the zinc ore and extract the sulphur dioxide gas before the ore is distilled

CRUSHING MILLS AND COKERS



In these four Chilean mills the mixture of sintered zinc, crushed coal and binding material are crushed and bound together to make the briquettes in the first stages of extracting the pure zinc from the blende

There are several ores from which zinc is obtained, but blende (sulphide of zinc) is the main source of supply. After the ore has been crushed it is pressed into the form of briquettes. These are then "coked" before going to the vertical retorts, where the pure zinc is extracted. This photograph shows the briquettes being discharged from the cokers

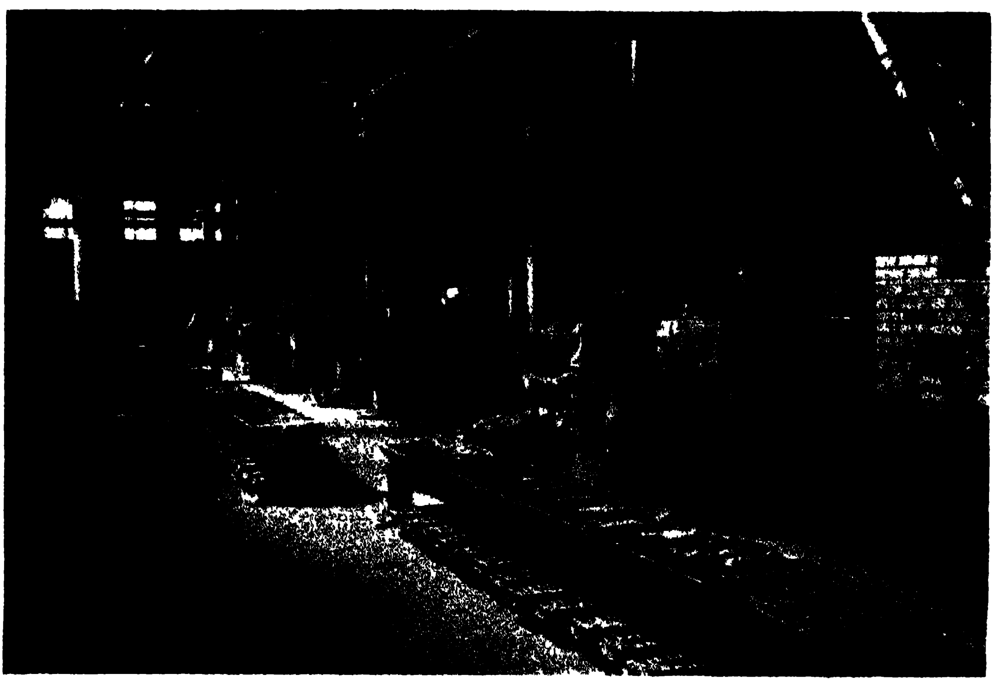
graphic plates owing to the quality of the material being easily etched.

A small quantity of other metals are added to zinc of the highest commercial purity, which is 99·99 + per cent., to produce a zinc alloy sold under the trade name of Mazak. Mazak is used for pressure die casting. Pressure die casting is the name given to describe the action of forcing molten metal under pressure into a steel mould for the production of castings, which can be extremely complex. It is a process which is unexcelled for rapid production of parts.

The number of articles produced from Mazak is legion. They vary from zip fasteners to motor-car radiator grilles, carburettors to model railway engines. It is a durable material to which organic or chemical or plated finishes can be applied.

Though zinc is applied in various forms to many other everyday uses it cannot be left without some mention of the very important zinc pigments. One of these is zinc oxide, a fine white powder which is used in paint and enamels as a pigment and as an ingredient in rubber to make it tough and resilient ; it is used in linoleum and leathercloth too. In pharmacy its antiseptic qualities find outlet in zinc ointments, adhesive plasters, soaps and cosmetics.

Another pigment is zinc sulphide , this is the basis of one of the most important white pigments, known as lithopone. Lithopone was invented by Mr. John Bryson Orr, a Scottish chemist, in 1898. Mr. Orr, when experimenting, discovered that a mixture of sulphide of zinc and sulphate of barium made a white pigment of great opacity. The chief uses of the pigment are in the paint, linoleum and rubber industries, where it is used as a basis for bright colours ; it is also used in many others, such as cable, leathercloth, celluloid, asbestos and paper.



CASTING ZINC SLABS

The number of articles of everyday use which have been " galvanised " or coated with zinc is legion, while sheet zinc is used extensively in many trades. Here we see high purity zinc being cast into slabs, in which form it is easily handled

TIN AND TIN PLATE

Photos by courtesy of the Tin Research Institute

IN A MODERN FRUIT-CANNING FACTORY

Canned foods have become an essential part of our daily menus, and the " tin-opener " an important item in the kitchen equipment. For fruit-canning, high-grade hot-dipped coatings of tin are used, and here we see the " tin cans " being filled with fruit. How tin is obtained and its many uses are dealt with in these pages.

TIN is found in the form of oxide, cassiterite, sulphide, and stannite ; very rarely is it found as native tin. The ore is usually sparsely scattered through igneous rocks, of which granite is typical, as an intrusion into the cracks which developed when the rock was cooling after solidifying from the molten state. These intrusions take the form of thin veins, or, occasionally, of small isolated lodes.

In Cornwall, these veins or lodes are generally at a fairly steep slope to the horizontal ; they vary in thickness from a millimetre up to several inches in thickness, but each vein may be many yards in width. Veins and lodes are generally located at all depths down to 3,000 feet or even deeper.

In Bolivia similar granite masses containing tin form a high plateau of the Andes mountains, rising from 12,000 to 15,000 ft. Other lode mining areas are in the mountains of Czechoslovakia, and in the north of Spain ; there is also a lode mine at Pahang in Malaya.

The alluvial mining areas in Malaya, Indonesia, and elsewhere, have come about by the granite rock being reduced during millions of years to fine sand, and in some cases to kaolin (china clay). The cassiterite is found in fine particles in alluvial mud and gravel brought down from the mountains by the rivers.

At present the total world production of tin in ore is some 167,000 tons a year. Lode mining in Bolivia yields 31,000 tons ; in Europe, including Cornwall, 2,700 tons are produced ; from alluvial mining Malaya produces 58,000 tons ; Indonesia 32,000 ; Siam 10,000, while the Belgian Congo produces some 15,000 tons annually. China 3,600, Nigeria 8,000, Australia

2,000 tons, with another 5,000 tons from other countries completes the world's supply.

It is obviously cheaper to recover the tin ore from alluvial deposits, already naturally disintegrated, than from lode mines where miners have to blast and hew tunnels through one of the hardest of rocks.

Mining Alluvial Ore

Various methods are used in mining alluvial tin ore, but usually it is done in open-cast quarries or by dredging. In open-cast working the top soil is removed to expose the tin-bearing clay or gravel, and the pit is continually enlarged and deepened in terraces. Where bull-dozers, scrapers, drag-lines, and power-operated shovels can be used, the open-cast terraces are worked simultaneously at several levels, and the crude ore carried away to the washing station nearby. In some area mechanised methods are unsuitable and hand shovels are used, the ore being transported in baskets.

Another method is to wash away the sides of the pit with powerful water hydrants ; the mud bearing the tin collects in sumps and is brought by gravel pumps to the top of a long ramp (or palong, as it is known in Malaya) sloping down into the pit, and divided every few yards by a cross board where the tin ore can sink while lighter material passes over.

The most effective method, however, is to form a lake or paddock in the deposit and launch into it a bucket-dredge assembled beside it. The boom with its chain of huge buckets may be capable of reaching 150 feet depth, and the dredge is firmly tied to the bank so as to enable the buckets to scrape away the tin-bearing earth. The sand and clay brought up by the buckets is discharged into a rotary sieve or trommel in which jets of water free the heavy tin ore.

Crude tin ore obtained by these methods is crushed, washed, and sieved; it may contain some iron and copper oxides and sulphides, or other valuable metals, which are then separated. This is done by a flotation process in which oil is used. Further processes are used to obtain a good separation, after which the dry "concentrate" containing about 70 per cent. of tin is sent to the smelter.

Refining is generally done in a reverberatory furnace where the molten metal lies in a shallow pool a little below the arched ceiling of fire-clay from which the heat of burning gases is reflected into the metal. Further purification is effected after this treatment in the furnace, and, indeed, the refining operations are repeated many times before the highest quality of pure tin is obtained.

Properties and Uses

Tin has a low melting point (232° C.), is able to resist corrosion, and, when molten, to "wet" cleaned surfaces of steel, copper, brass and other metals, and to adhere to them after cooling down ; it is ductile (flexible), and it will alloy with many common metals. Its main uses are for coating, for alloys, and in chemical compounds. Coatings are applied by either electrodeposition or by hot-dipping. In addition, tin coatings may be produced on articles by spraying them with fine particles of tin, or by immersing them in solutions of certain tin compounds.

In the electrodeposition method the cleaned article is suspended as the cathode in a tank containing the electrolyte, which is a solution of sodium stannate ($Na_2SN\ O_3$) or of stannous sulphate ($Sn\ So_4$). Anodes of pure tin are suspended two or three inches from the object. A current of about 15 to 30 amperes per square foot, and at from 3 to 5 volts usually, is passed for a few minutes, or, if a thick deposit (one-hundredth of an inch) is required, for as long as an hour. The sodium stannate bath works at 80° C., but the stannous sulphate bath can be

DREDGING FOR TIN

Nederlandish Foto Bureau

The larger part of the world's tin supply is got from tinstone, black oxide of tin, found near the surface mixed with gravel or earth. This huge floating dredge is scooping up tin bearing gravel with its great steel buckets. These dredges are so efficient that it is worth while treating deposits containing as little as one pound of tin ore in three tons of sand and clay.

IN A CORNISH TIN MINE

Cornish tin was used by the ancient Phoenicians and the Romans. To-day, Cornwall still produces tin, but the mines have become deeper and water seeps in, as seen in this photograph of trimmers hauling trucks in the East Pool Mine.

worked cold. This process is much used for tinning parts which are to be soldered later.

Coatings of tin can also be produced on steel, copper and brass without passing any external current, merely by tying round them a wire of aluminium and immersing in hot sodium stannate for a few minutes or up to two or three hours. This method is useful for inaccessible places.

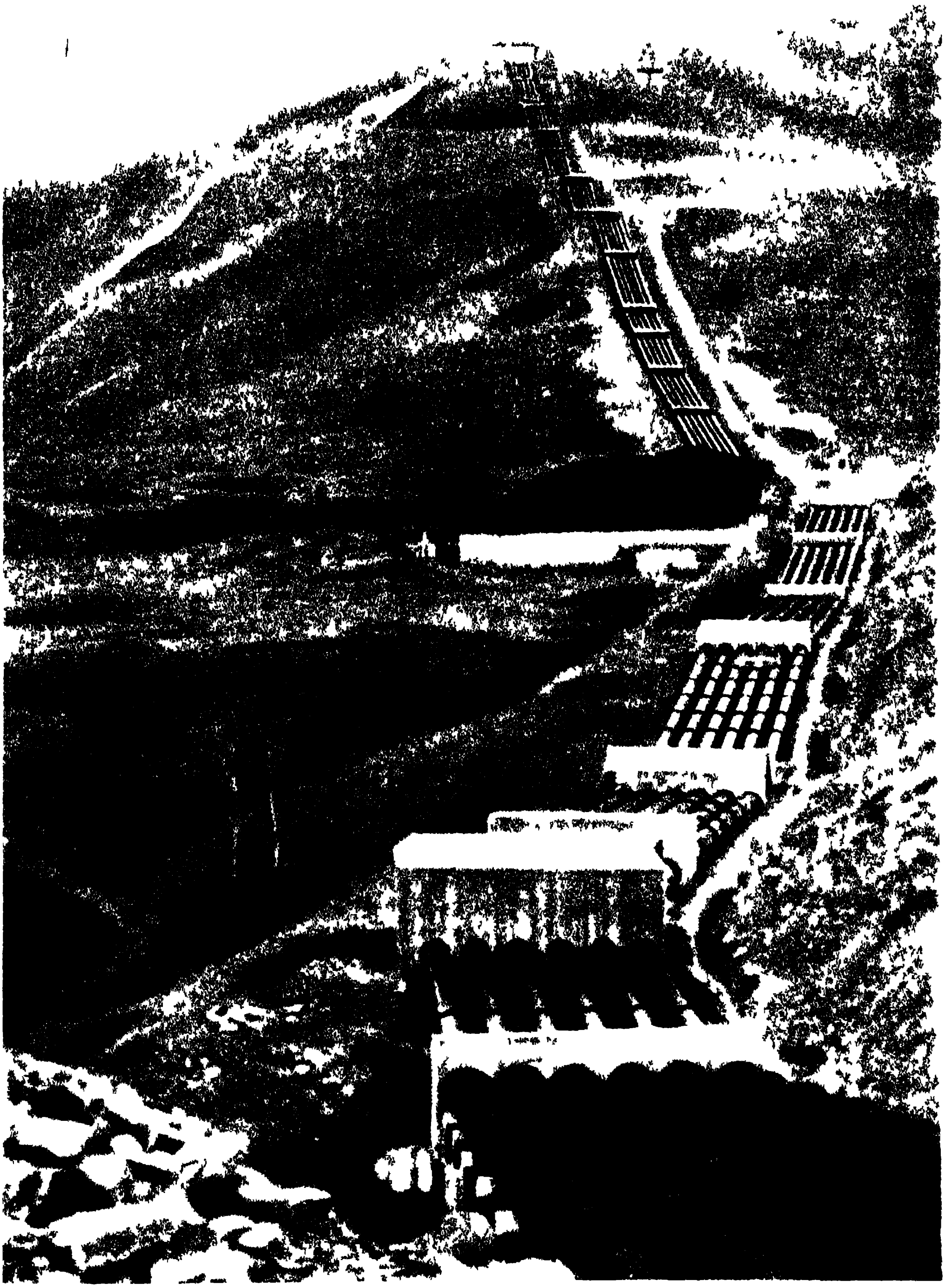
Tin coatings by the hot-dipping process are produced by cleaning the surface, covering with a flux solution, and heating in contact with molten tin. The tin may be molten in a pot, or applied as a wire or powder which is then melted on the metal surface; excess tin is drained off by gravity, or by spinning the article, or by wiping ("wiped" tin coatings).

Hot-dip coatings generally range from one-thousandth of an inch down to half this when freely drained. In tin plate manufacture, coatings down to about one tenth this thickness can be obtained by squeezing off surplus tin between rollers working in hot palm oil.

Tinplates usually carry about 70-millionths of an inch of tin upon each side. The manufacture of tinplate began three or four centuries ago with the hand-tinning of small sheets of iron, and then about a century ago the process became mechanised. Twenty-five years or so ago, methods of producing steel sheet in continuous coils were developed in the U.S.A. This continuous sheet is preferred for tinplate manufacture because it is purer, more ductile, and more free from defects. It has to be cut up into sheets before it can be tinned.

The electrolytic variety of tinplate is always produced in continuous coils. The steel coil passes at speeds of five to ten miles an hour through long, shallow baths containing tin compounds in solution. Current passes in from pure tin bars (anodes) immersed in the solution, causing them to dissolve, and passes out through the strip of steel, depositing tin on it at the same time. After washing and drying, the strip is "flow-brightened" by passing the coil quickly through a zone which is just hot enough to fuse the tin coating.

The rate of deposition of tin is slow and very long baths would be needed to deposit the same thickness of tin as there is on ordinary tinplate. Electrolytic tinplate coatings are therefore thinner, generally about a third of the coatings with hot-dipped tinplate.



By permission of the British Aluminium Co. [partly illegible]

HOW SCOTLAND'S WATER DRIVES AN ALUMINIUM WORKS

In recent years the use of Aluminium [illegible] with other metals has [illegible] being particularly valuable in the [illegible] [illegible] utensils [illegible] aluminium [illegible] electrical treatment [illegible] generation [illegible] water. In this picture is seen the pipe [illegible] aluminium works at [illegible]

N. K. [illegible]

For canned foods of the more corrosive types, such as fruits, hot-dipped coatings of high-grade are used. The electrolytic grade, with or without the addition of one or more coats of lacquer, has a large field in packing less corrosive foods and for dry materials such as coffee.

Hot-dipped coatings are generally used for milk cans and other dairy equipment, whether of steel, copper or gunmetal, and also for kitchen equipment such as mincers, sieves, mixing-bowls, etc.

Sprayed tin coatings are commonly used for large pieces of equipment that cannot be handled by ordinary means, for example, large dough mixers, milk tanks and food-preparing vats.

Immersion coatings are extensively used on pins, eyelets, and similar small articles, particularly screws and other threaded parts where clogging of the thread must be avoided.

Tin coatings as a preparation for soldering are preferably of the hot-dipped kind, but may be of tin-lead alloy instead of tin.

Steel and copper wire are tinned by drawing them through baths of molten tin or tin-lead alloy and wiping off the excess tin by means of a rubber or asbestos wiper.

Pure tin is used for the manufacture of high quality foils for electrical condensers and for wrapping cheese and a few other food products. Additions of less than 2 per cent. of antimony and copper are made to the tin in such cases.

The addition of about 4 per cent. antimony and up to 2 per cent. of copper produces pewter and Britannia metal, which are mostly used for decorative purposes, but are also useful as corrosion-resisting alloys for contact with vinegar and certain other common substances.

Jewellery can be cast quite cheaply in this alloy, using rubber moulds. The addition of 7 to 10 per cent. antimony and from 2 to 7 per cent. copper transforms tin into bearing metal of the

GOING DOWN IN THE LIFT

A good deal of the world's supply of tin is now obtained from alluvial mining, but lode mining also produces 34,000 tons annually, of which Cornwall supplies some 2,700 tons. In this photograph a group of miners is seen just before going down in the lift to the deep workings.

highest quality for use in reciprocating engines. With even higher proportions of antimony, the alloy is harder and is much used for soda siphon tops and pressure die-cast counter mechanisms, valves for gas meters, etc. Other alloys of tin are used for the bearings of such appliances as electric motor dynamos, ship's propellers, and railway carriages and wagons.

Solders may have 100 per cent. tin down to about 20 per cent., and even much lower for special purposes. It depends on the work for which the solder is required

One might go on at considerable length in mentioning all the articles in which tin and its alloys are used. Type metals are made of lead hardened with 15 per cent. of antimony, and toughened with from 4 to 12 per cent. of tin ; the more tin the tougher the type and the longer it will last without becoming worn and flattened.

Bronze is an alloy of about 90 per cent. copper and 10 per cent. tin. Gunmetals are similar but contain from 2 to 5 per cent. of zinc as well. Bell metal is bronze with about 20 to 25 per cent. of tin. The colour is a greyish pink, and this alloy is extremely hard and resonant.

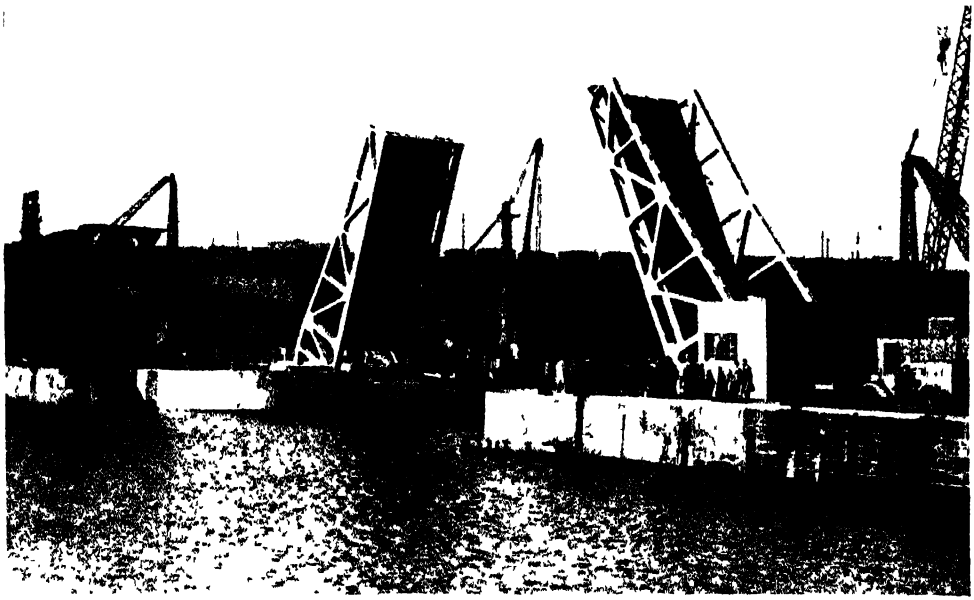
Since the introduction of the electrolytic process of manufacturing tinplate, the most important compounds of tin are those needed for electro-deposition : stannous sulphate and sodium stannate. More stannous sulphate is used than stannate.

Tin oxide is generally prepared from tin metal or tin recovered from scrap since the natural oxide (cassiterite, tin ore) is not capable of being purified sufficiently. It is a dense white powder, insoluble in water and acids, only slightly soluble in strong alkalis, but is dissolved by fused caustic soda. Its chief use is in ceramics and in porcelain enamels used on iron and steel, for which it is unsurpassed Organic compounds of tin, such as dibutyl tin maleate, have in recent years become important in the manufacture of clear plastics as they prevent the spontaneous clouding and darkening to which some types of plastic products are liable.

A TIN MINE IN BOLIVIA

High up in the Andes, granite masses containing tin form a plateau at 12,000 to 15,000 feet. Working at this altitude is difficult and inevitably costly, but some 31,000 tons of tin are produced annually in Bolivia. Our photograph shows the portal and main haulage level of a Bolivian tin mine.

THE STORY OF ALUMINIUM



Topical Press

THE FIRST BRIDGE MADE OF ALUMINIUM ALLOY

Many experiments have been made to combine the lightness of aluminium with other materials having strength and toughness. These experiments have produced valuable alloys and in this photograph is seen the first aluminium alloy bascule bridge in the world. It spans the junction between the Hudson and Hendon Docks at Sunderland, and was opened in November, 1948.

ALMOST every kitchen nowadays contains some saucepans, kettles and other cooking utensils made of aluminium. And for a very good reason, since this silvery-looking metal is only about one-third as heavy as iron, conducts heat excellently, does not tarnish or rust, can be cleaned easily, and will stand a lot of knocking about.

The qualities of lightness and freedom from rusting make aluminium useful for many other purposes, such as the crank-cases of motor cars, name-plates, mats, ornamental fittings, reflectors, telescope tubes, and so on. The metal conducts electricity so well that large quantities are made every year into wires for insulated cables and overhead conductors, and parts of electrical apparatus.

Aluminium is one of the commonest elements in Nature. An acre of clay-land contains tons of it; even in a small back-garden aluminium lurks in no mean quantities.

But it is always combined with other elements—oxygen, hydrogen, sodium, chlorine, silicon—and the difficulty of separating it from them made it a very expensive metal, costing at one time much more than silver. About the year 1890 a method of parting it from its companions by means of electricity came into use. The price then fell with startling rapidity, and to-day aluminium costs hardly more than copper.

Between Rods and Lining

The story of aluminium begins in a deposit of a kind of clay, named bauxite, near Arles, in France, or Larne, Ireland, or in Alabama, Arkansas, or Georgia, U.S.A., or in British Guiana. This mineral is white or red in colour, and a chemist would describe it as

impure hydrated oxide of aluminium, which means a combination of oxygen, aluminium and water.

To pick up all the threads we have also to go to Greenland, where is found a great abundance of another compound of metal, called cryolite. For this substance, too, is needed in the manufacture of aluminium.

We must also put on our list a great electrical power-station, where electricity is generated cheaply by falling water—at Niagara, at Foyers and Kinlochleven, in Scotland, or elsewhere.

Imagine, then, the bauxite and cryolite brought together at the factory, which itself is near the power-station. In the factory are large carbon crucibles, each having an iron plate in the bottom, and over each box is a bundle of carbon rods. The iron plate is connected with the negative pole of the electric generators and the rods with their other pole.

By Electric Flame

A man lowers the rods against the lining and draws them away again. An intensely hot arc, or electric flame, is created between the rods and the lining. Cryolite is thrown in, and the intense heat melts the cryolite. Then bauxite is added in a steady stream. The aluminium in it is melted out and sinks through the cryolite to the bottom of the crucible, from which it is drawn off at intervals. The oxygen in the bauxite combines with the carbon of the rods to form a gas, which passes off into the air.

Aluminium is a very " kindly " metal to work. It allows itself to be rolled out, or drawn into wire, or squeezed and hammered to any desired shape. For saucepans, it is rolled into sheets, out of which circular pieces are stamped. Then each piece is placed between dies and its edges are turned up, and, behold! the body of a saucepan. To this a handle is riveted to make the article complete. The saucepan is a good thick one, holds half a gallon, and weighs 14 ounces. Its cast-iron companion, of the same size, weighs over 3 pounds.

As an Alloy

Pure aluminium is not a very strong metal. But if mixed with a small proportion of other metals, such as copper, zinc and iron, it makes a very light but strong alloy. These aluminium alloys are used for the pistons and connecting-rods of motor car engines. Engines of this kind have to run at very high speed, and they may make up to 5,000 revolutions a minute. Every time a piston reaches the end of a stroke it and its connecting-rod have to be stopped and moved in the opposite direction. The saving of even a few ounces is therefore a great gain, as the engine then has to waste much less power in repeatedly checking and speeding-up these parts.

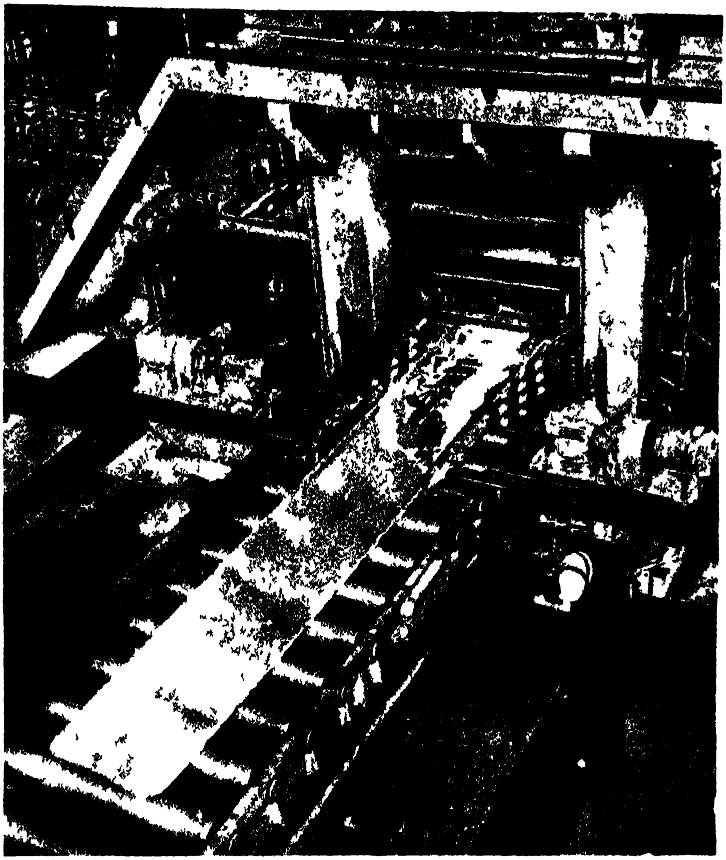
Aluminium is used in an interesting way for welding tramline rails together end to end. A mould of fire-clay is first arranged on each side of the join and below it, to prevent the escape of the metal poured in to fill the space. A large crucible, rather like a flower-pot in shape, is placed over the joint and filled with a mixture of powdered aluminium and oxide of iron.

When the mixture is set alight by a special fuse, the oxygen in the oxide combines with the aluminium so fiercely that the iron is melted out and heated far above the melting-point of iron. The workman now presses down a lever, which makes a hole in the bottom of the crucible for the iron to run out through. The liquid iron not only fills the gap between the rails but melts their ends, so that when the joint cools the two rails become one.

Hundreds of experiments have been made by metallurgists to discover ways in which the desirable property of lightness which distinguishes aluminium from most other metals could be combined with other properties such as high strength, toughness, and freedom from corrosion. The first important

discovery which was made was that if a small amount of copper and a still smaller amount of manganese were added to pure aluminium, the hardness and strength were considerably improved. It was also found that if this metal is heated and quenched and then left to "age" for some time, its properties improve very considerably. This metal is known as Duralumin.

Many other aluminium alloys have been developed, and a method has also been perfected for producing Duralumin sheet with pure aluminium on each side to protect it from corrosion. This material, which has been largely used for aircraft, is called "Alclad."



British Aluminium Co Ltd

A "BREAKING-DOWN" MILL

The first stage of the flattening-out process, known as "breaking-down," is done in this machine, which shows the hot rolling of strong alloy strip in a 96 in wide "breaking-down" mill at the Falkirk Rolling Mills.

Lighter than Aluminium

A metal which weighs even less than aluminium is magnesium. Practically every schoolboy will remember the laboratory experiment with magnesium ribbon which can be set on fire to give a blinding white light accompanied by clouds of white smoke. Although magnesium is so readily inflammable when it is in the form of a ribbon or a very thin strip, it can be used quite safely when it is formed into the shapes and sizes required by engineers in the construction of aircraft and aircraft equipment.

By mixing small quantities of other metals with it, *e.g.*, aluminium and manganese, magnesium can be used for the production of alloys which have extreme lightness combined with reasonable strength. One of the best known of the aluminium-magnesium alloys is Magnalium.

The problem of light-weight metals has become increasingly important in recent years. In the construction of aircraft and motor-cars its advantages are obvious, but the use of aluminium alloys is extending steadily in less likely directions. Towards the end of 1948, for instance, the first bascule bridge in the world to be made of aluminium alloy was opened in Sunderland.

THE METAL OF SATURN—LEAD

Photos by courtesy of Associated Lead Manufacturers Ltd

LEAD WORKS AND SHOT TOWER AT CHESTER

Lead was one of the metals known to the ancients and its uses are many. The Shot Tower seen in this photograph of the lead works at Chester was constructed about 1800 and is over 156 feet high, and inside it is a spiral steel staircase having 198 steps. This tower is still in operation making shot to-day

ONCE I had to examine the sea-bottom round the end of a pier. To do this it was necessary for me to get into a diving-dress, a costume which I had never had occasion to wear before. When it was on me, my feet were encased in boots with leaden soles, weighing about 16 pounds apiece. The last items of the outfit to be attached to me, as I stood on the ladder leading down into the water, were two flat plates of lead, each scaling 40 pounds, fixed one on my back and the other on my chest.

"Heavy as Lead"

At this stage I realised the full meaning of the expression, "heavy as lead." I felt almost crushed under the unusual load. But as soon as I was in the water, with the dress blown out by the air pumped in, I knew that every pound of it was needed to keep me on the bottom and reasonably steady on my legs. Had the weights slipped off, I should have bobbed up to the surface like a cork.

Heaviness, then, is a very obvious quality of this metal, and one that makes it useful wherever a great deal of weight has to be got into a small space at reasonable cost. Racing yachts, for example, carry many tons of it—anything up to 100 tons—in their deep keels to overcome the capsizing effect of their huge sails. We use leaden bullets and shot because, among other reasons, they travel farther than would bullets and shot made of a lighter metal, if discharged at the same speed.

Lead is not, however, by any means the heaviest of metals. Let us just see where it stands in this respect among its fellows: A block of lead measuring a foot every way weighs 710 pounds, which is about eleven and half times the weight of the same bulk of water. One of zinc would scale 427 pounds, one of cast iron about 470 pounds, one of

VEINS OF GALENA
This close-up photograph of lead ore on top of a loaded wagon shows the veins of galena, from which the lead is extracted, in the large stone before crushing

copper 547 pounds, and one of silver 650 pounds. So lead has all of these metals well beaten as regards weight. But it is easily outweighed by quicksilver, with its 847 pounds to the cubic foot; by gold, at 1,200 pounds: by platinum, at 1,260 pounds; and by the very rare metal, iridium, which, when compressed by hammering, weighs just twice as much as lead.

Lead and its Uses

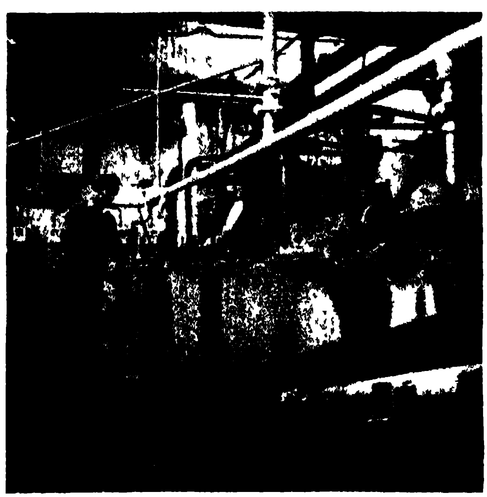
Besides great weight—which is not always an advantage—lead has other qualities which make it useful to us. It is easily melted and cast into any desired form. It is so soft that it can be readily rolled or moulded by beating while cold. It is acted upon hardly at all by air and water, and is wonderfully durable. You may see to-day in the British Museum lead pipes and fittings used by the Romans 2,000 years ago, and still practically "as good as new."

About 1½ million tons of lead are used up every year. Of this over 500,000 tons a year are used in the manufacture of electrical accumulator plates, while about 300,000 tons are forced in a semi-molten state through dies to form pipes or in making electric cables. In addition, considerable quantities of lead are rolled out into sheets for covering the flat parts of roofs and for lining tanks, while about 250 tons are used in red lead and litharge and another 50,000 tons in white lead.

Then there are the valuable alloys of lead, including pewter and solder, while a mixture of lead and antimony gives us type-metal, without which the printing industry could scarcely exist.

Lead also plays a very important part in connection with our water supplies, for when water mains are laid the joints between the pipes are made water-tight by hammering lead tightly into them. We have its help even when drinking water, since tumblers, like many other glass articles, contain a large proportion of lead—though it is quite invisible. Even our teacups and saucers may have lead in them as lead forms part of some glazes used on chinaware and pottery. Lead was at one time used in making the popular "tin" soldiers and many other toys, but other lighter materials, particularly plastics, are more generally used to-day.

It will be seen, however, that if some magician could by a wave of his hand banish all lead from the world we should be in a sorry plight as water burst in or



CONCENTRATING THE LEAD
Much of the earthy material is separated during the crushing of the ore; later, the lead is concentrated by the flotation process which is seen in this photograph.

IN THE LAKE DISTRICT

It is very probable that the Greenside Mine was first discovered in Roman times. Situated about a mile from Lake Ullswater on the eastern slopes of the Helvellyn range, it is the oldest producing mine in the North of England.

out upon us in all directions, electrical cables broke down, paint peeled off on every hand, and a number of other very unpleasant things happened.

A Little Word-family

The Latin word for lead, ***plumbum***, is the father of several English words in common use. Two of them, " plumb " and " plummet," signify a heavy weight (usually of lead) attached to the end of a cord to plumb, in the sense of find the depth of, water or deep holes. A sailor plumbs the sea when he takes soundings by " heaving the lead." A mason plumbs a wall when he tests its uprightness by means of his plumb-bob. To plumb may, again, mean to work in lead. A man who does such work is called a plumber, and his work is plumbing.

Then we have the word plumb as an adjective, meaning vertical. The famous Leaning Tower of Pisa, in Italy, is out of plumb—out of the perpendicular—by rather more than 16 feet. Plumbago, also called blacklead, has crept into the family under false pretences; for plumbago has nothing whatever to do with lead, being pure carbon.

We have already mentioned small-shot. Have you ever wondered how the pellets came to be as perfectly spherical as if each had been cast separately in a tiny mould? One cannot imagine shot-makers using moulds and making a profit. As a matter of fact, they let Nature do the moulding for them.

Molten lead, mixed with a little antimony to make it more fluid, is poured through a sieve fixed at the top of a tall tower or old mine-shaft. The sieve is punched with holes as large across as the shot is to be. The lead flows through these holes in many streams, which break up into drops as they fall, and each drop has time to obey a law of Nature and become a sphere before, after travelling 150 feet or 200 feet, it reaches a tank of cold water and hardens instantly.

Now some of the pellets get knocked out of shape. They are sorted from the perfect shot in a simple but ingenious way. All the shot is sent down a sloping shoot. The perfect shot get up enough speed to leap over a gutter lurking at the bottom, while the badly-shaped ones, hobbling along at a slower gait, fail to do so, and are trapped.

Where Lead Comes From

At one time British mines yielded over 70,000 tons of lead a year, and a large army of miners was employed in the lead-mines of Derbyshire, Northumberland, Cumberland, Yorkshire, Somerset, the Isle of Man, and several places in Wales and Scotland. To-day the British output is not much more

than about 4,000 tons a year, but it is still carried on and by modern machinery. One of the largest lead mines in England is the Greenside Mine situated in the Lake District, about a mile from Lake Ullswater, on the eastern slopes of the Helvellyn mountain range. It is probable that this mine was discovered in the days of the Romans, though modern operations only date from the latter part of the eighteenth century. In the early days ore from the mine was conveyed for smelting to the neighbourhood of Keswick on the backs of horses.

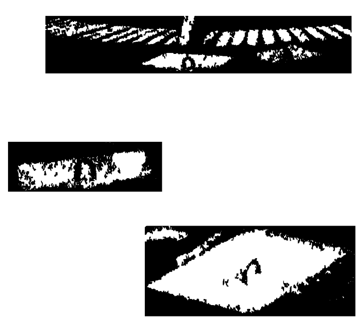
To-day the United States are the largest producers of lead and over one-quarter of the world's supply comes from them ; Mexico supplies 230,000 tons, Australia 200,000 tons, and Canada 150,000. No other country produces more than 100,000 tons and Spain's output is now only about 40,000 tons annually.

The two chief lead ores are named galena and cerussite. The first of these, which is sulphide of lead, has a sparkling crystalline and silvery appearance. Small pieces of it were often used in the crystal detectors of early wireless sets. Cerussite, which is carbonate of lead, occurs as white or coloured crystals. The metal is extracted from the ore by smelting in a furnace.

Queer Beliefs about Lead

Most lead contains more or less silver, which is separated from the lead if the quantity present justifies the expense of doing so. The oldest of the several processes used is named cupellation. The lead is heated in a furnace and air is blown over it. The oxygen in the air joins forces with the lead and forms lead oxide, also called litharge. The silver refuses to combine and is left behind. The lead in the litharge can be recovered by mixing the substance with carbon and heating it, when the oxygen in it goes into partnership with the carbon as carbonic acid gas and parts company with the lead.

In his " Canterbury Tales," the old English poet, Chaucer, tells us that each of the seven metals then known was connected with one of the heavenly bodies. Gold belonged to the sun, silver to the moon, quicksilver to Mercury, iron to Mars, tin to Jupiter, copper to Venus, and lead to Saturn.



WITH THE TAPPING GANG

Here we have a view inside the Refining Shop at the Associated Lead Manufacturers' works at Millwall, showing the tapping gang at work as the molten lead runs into the moulds.

The last-named planet had a very bad reputation among astrologers, for Saturn was none other than old Father Time, who reaps away men's lives with his scythe. And lead was looked upon as the worst of metals, because many compounds of it are very poisonous to man, beast and vegetation. So, in the sharing out of metals, Saturn very properly was made a present of lead.

The old alchemists taught that lead, like all other solid metals, was derived from quicksilver and sulphur. They hoped that, by purifying the mixture, they would change the " base " metals, of which lead is one, into the " noble " metal gold. In their hunt for a short cut to wealth they used up great quantities of lead ; and it is not surprising that, instead of adding to their riches, many of them had to part with such gold as they already possessed.

Lead, however, has figured in history both for its harmful as well as its many useful properties. It is mentioned in the Old Testament in Numbers and in Job, and it constituted part of the spoils which the Israelites took from the Midianites. The Romans, as we have seen, worked lead mines in England, and the archæologists have found some fine examples of the lead work of early Saxon times.

On the dark side is the danger of lead-poisoning which was at one time a serious threat to workers in industries where the metal is used Workers in the Potteries employ lead glaze, while painters, plumbers, printers and others have suffered unpleasant consequences owing to minute doses of lead being absorbed over a long period. Among the ill-effects was a kind of paralysis which attacked the nerves of the arm and produced a condition known as " wrist-drop."

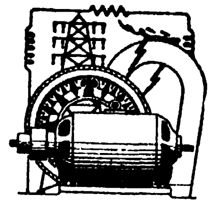
Preventive measures are now taken to protect workers liable to be affected ; these include the wearing of overalls, and, where necessary, respirators ; baths are provided and employers must see that they are used by the workers where it is considered necessary ; frequent medical examinations are made, and acid drinks are provided : these tend to remove any lead from the system.

In such ways the ill-effects of lead among those who use it have been greatly diminished ; among the many wonders science has wrought in recent years it may be assumed that the elimination of lead-poisoning among those who work with it will be recorded in due time. Lead is far too valuable a metal to be allowed to retain its reputation for evil.

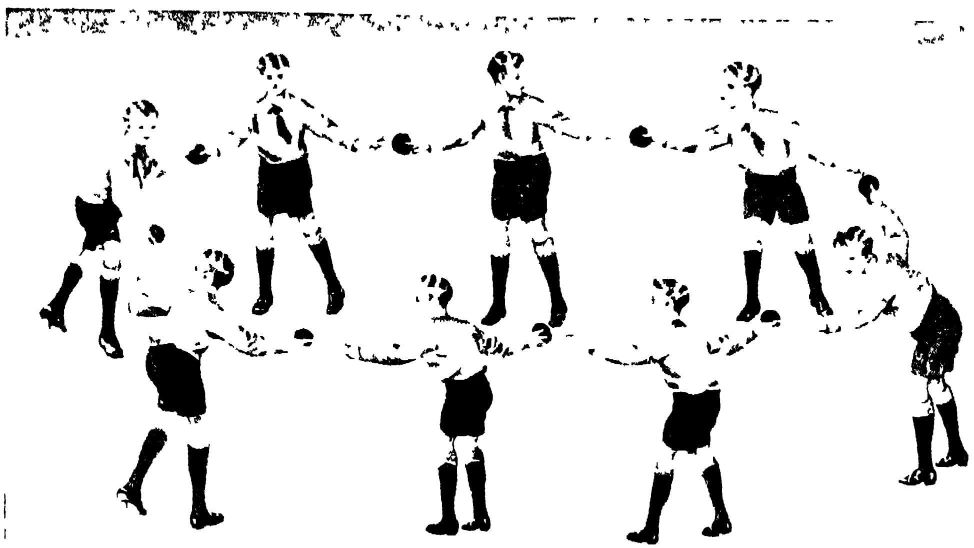
IN THE SHEET ROLLING MILL

Lead, being very malleable, is easily rolled into sheets after first being cast into cakes about 5 feet square. This shows the sheet rolling mill in operation at the Millwall works.

Magnetism and Electricity



A Great Discovery and its Many Developments



Specially drawn for this work.

HOW ELECTRIC CURRENT FLOWS

These boys represent the atoms of a conductor through which a current is passing, and the oranges that they are handing to one another stand for electrons being transferred from atom to atom. The atoms themselves do not travel as wholes.

ELECTRICITY AND ITS USES

THE Greek poet Homer tells us of an "old man of the sea" named Proteus, who looked after the seals which made up the flocks of Poseidon, king of the oceans. He had the power of prophecy, and would tell the future of anyone who could hold him fast. This was very difficult to do, for he changed into one shape after another, and proved himself a "very slippery customer."

Electricity is rather like Proteus. It is very difficult to keep hold of. If you are not very careful it will wriggle out of your grasp, often without making any sign of how it does so, and you are left wondering where it has gone. Even its very nature has puzzled men for a long time past. One theory after another has been built up, and then, hey presto! it has had to take another shape, and previous ideas about electricity are all upset.

Electrons—What are they?

The present view held by learned men about electricity is that *all matter* is electricity. Rather a shock, is it not, to have to look on oneself as all electricity, which one had before thought to be confined to wires, batteries, motors, and things of that kind?

Still, one has to respect this view of wiser people. Let us examine it a little. Matter is made up of atoms, it is said. It is also explained that every atom is a group of particles of positive and negative electricity. The

negative particles are called electrons, so this theory of matter is known as the electron theory.

Each atom may be compared to a core of paired-off positive and negative particles, with one or more rather loosely attached electrons revolving round it, as the planets revolve round the sun. The atoms of iron, gold, quicksilver, carbon, and the other elements differ only in the number and arrangement of electric particles they contain. As our bodies are made up of elements mixed together, it follows that—if the theory be correct—we are in effect electricity.

Boys, Oranges and Electricity

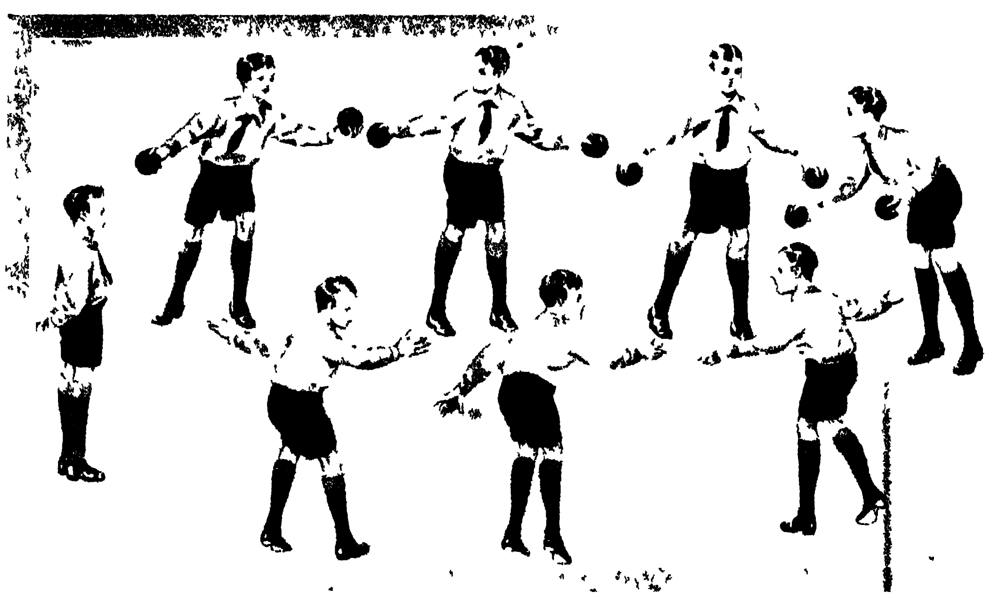
We have mentioned this new theory about matter only because it helps to explain in an understandable way what we speak of as an electrical current.

Imagine a number of boys arranged in a ring, each holding an orange in his hand. A boy represents an atom, and an orange represents one of those electrons which is not very closely bound to its atom. At a given signal every boy passes his orange to his right-hand neighbour and takes that of his left-hand neighbour. Each boy-atom still has an orange, but there has been a movement of oranges, and if the signal be repeated again and again the oranges will circulate right round the ring.

From Atom to Atom

When a current passes through a wire, then, we must regard it as a passing-on of electrons from atom to atom of the material of which the wire is made. A big current means that electrons are being passed in large numbers; a weak current that the exchange is limited.

Now an electric current does not flow without a reason. Let us see if we can find this reason: Going back to our ring of boys, let us suppose that the ring is broken at one point and that the passing continues in one direction,



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WHEN ELECTRIC CURRENT CEASES

The circuit has here been broken The two-orange boys are the part of a circuit into which electrons are being pumped from the other part, the no-orange boys. Immediately the circuit is completed again there will be a flow from the over-electroned "negative" side to the under-electroned "positive" side, and the passing along will be re-established

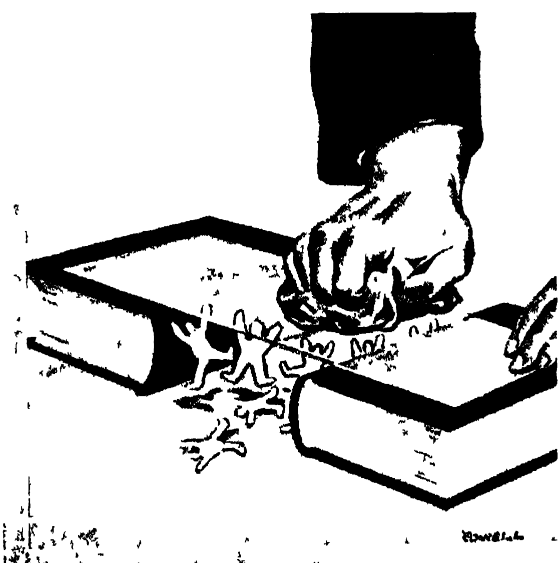
until half of the boys have two oranges apiece, and the other half none. The two-orange boys now separate from the no-orange boys. If things were left in this condition there would be dissatisfaction. The boys without any oranges would feel that they were owed one apiece by the two-orangers; and the last, being nice boys, would be quite willing to give them up. Everything is ready for a flow of oranges when the ring is re-formed.

In like manner an electric current is due to there being atoms in one place with electrons to spare (these are called "negative" atoms), and in another place "positive" or electron-hungry atoms which are short of electrons. The current is merely a distribution of electrons until matters are evened up.

Specially drawn for this work.

A SIMPLE EXPERIMENT

Rub a glass or ebonite rod with a silk handkerchief and hold it near small fragments of tissue paper. This is what will happen



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THE DANCING PUPPETS

Or place a sheet of glass thus over tissue paper puppets, and rub it well. Here again, the thing rubbed attracts light, loose objects, to make good a shortage of electrons

Electrified by Friction

Whence does electricity get its name? From the Greek word *elektron*, meaning amber. More than 2,000 years ago the Greeks had noticed that if a piece of amber were rubbed it became able to attract small, light bodies. For a long time people took little interest in the fact, but when it became an object of serious study this peculiar power was called electricity.

We know now that all bodies may be electrified by friction. If one rubs a fountain pen against the sleeve it will pick up small fragments of paper. Some kinds of cloth become electrified if brushed, and attract dust in an amazing manner; and the paper running through a printing press at high speed is apt to give trouble by its highly electrified condition.

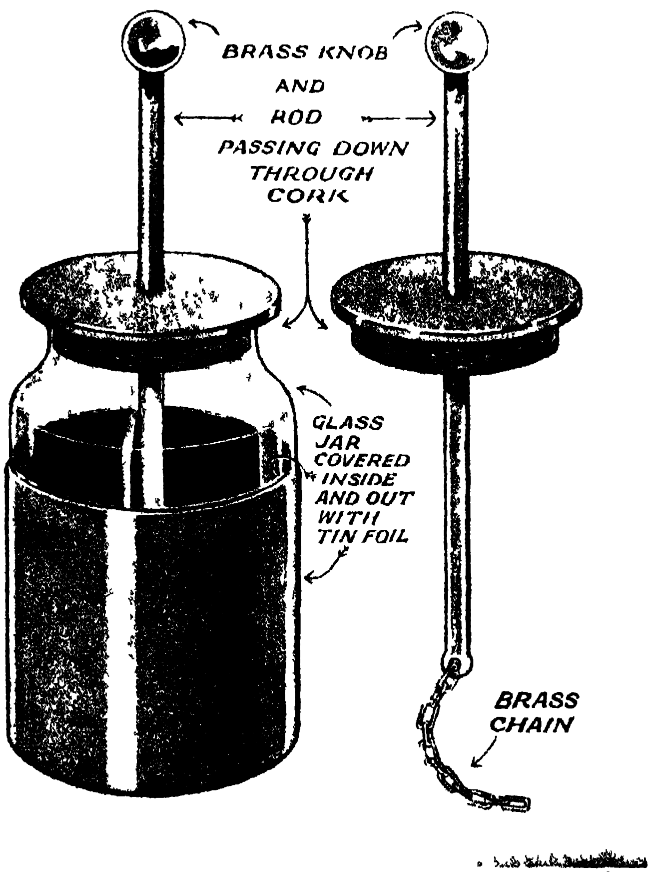
A Simple Experiment

Tear up a piece of tissue paper into small bits and lay them on the table. To right and left of them place a thin book, and bridge the gap with a sheet of glass. If the glass be now rubbed with a silk handkerchief the bits of paper will jump up from the table and cling to its under side, some hanging on for a long time.

In an earlier paragraph we spoke of electrons as parts of atoms. When the glass is rubbed, some of the looser electrons in it are picked up by the silk, leaving the glass rather short of electrons. The glass therefore attracts the bits of paper to extract electrons from them. As soon as they have given some up, and are no "richer" than the glass, they fall off again.

The Wonders of the Wimshurst Machine

One can steal electrons, as it were, without actual rubbing. Perhaps you have seen an apparatus called a Wimshurst machine. The chief parts of it are two flat circular glass plates revolving close to each other in opposite directions, and two Leyden jars. The last are glass jars covered part way up, both inside and outside, with tinfoil. A rod passes through the centre of a stopper of insulating material in the mouth of each jar, and a chain hanging from its bottom end touches the inner tinfoil.



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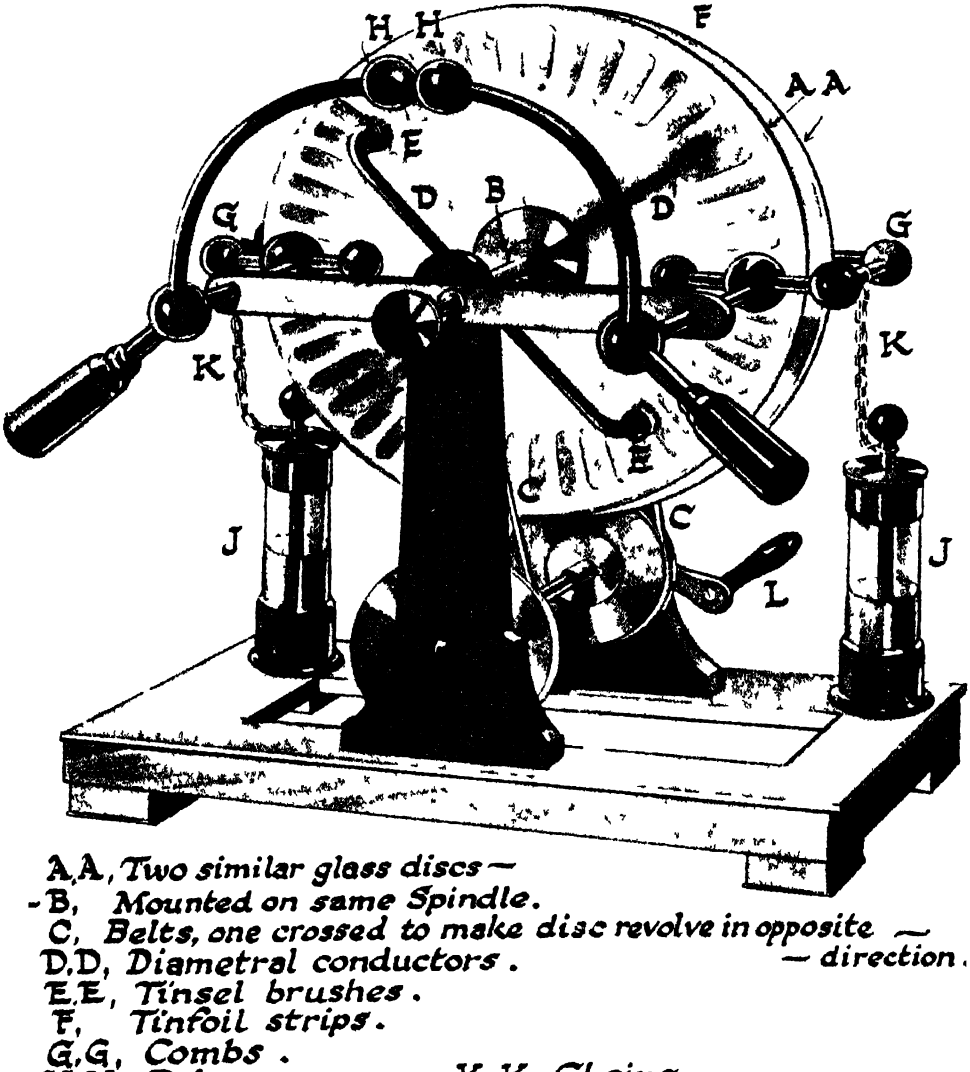
A JAR FOR ELECTRONS

This picture shows a complete Leyden jar on the left, and the insulated centre-rod separately on the right. The chain makes connection between the rod and the inside lining of tinfoil, which is completely insulated from the outside coating of foil by the glass of the jar.

Stealing the Electrons

The action of the spinning glass plates is to steal electrons from one jar and store them up in the other. If two knobs, connected with the jars, are brought close together, the electron-hunger of the robbed jar becomes too great to be borne, and there is a discharge of electrons to it from the other jar through the air, accompanied by a loud crackling noise and brilliant flash. This flash is really a succession of sparks, for the first discharge over-does matters, making the hungry jar overcharged; and many jumps to and fro may take place before the

A MAKER OF MINIATURE LIGHTNING

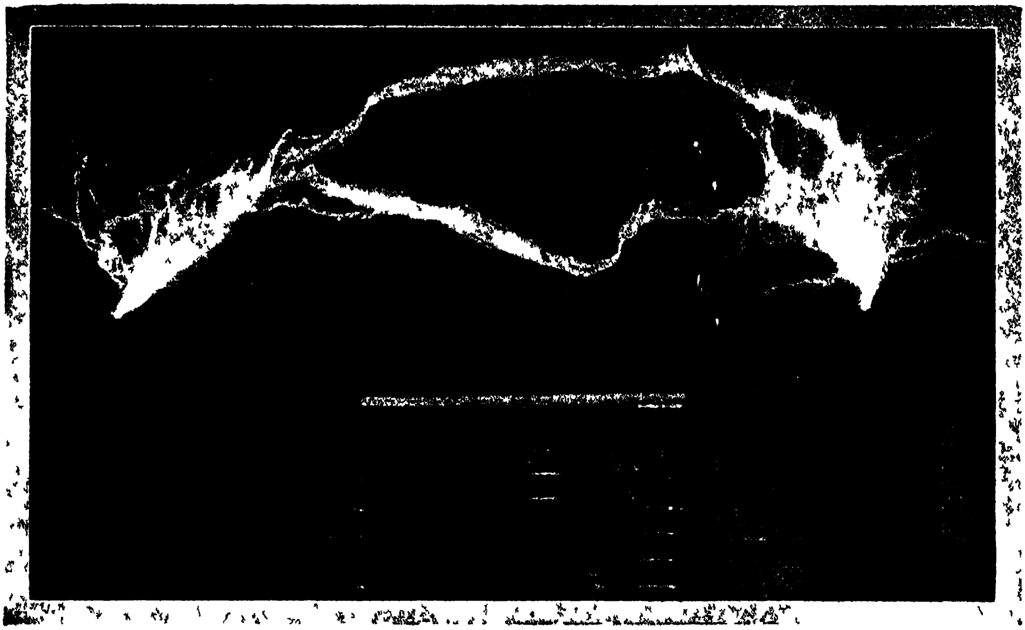


A,A, *Two similar glass discs —*
- B, *Mounted on same Spindle.*
C, *Belts, one crossed to make disc revolve in opposite — — direction.*
D,D, *Diametral conductors.*
E,E, *Tinsel brushes.*
F, *Tinfoil strips.*
G,G, *Combs.*
H,H, *Poles.*
J,J, *Leyden jars.*
K,K, *Chains.*
L, *Handle.*

Specially drawn for this work

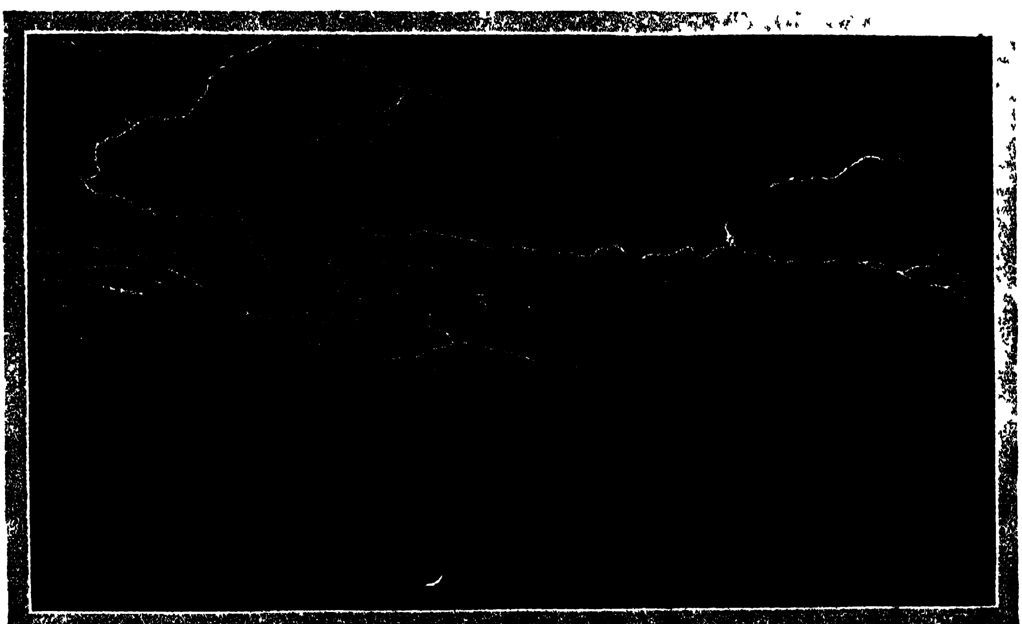
This is a Wimshurst machine If the knobs HH be separated and the handle L be turned, the effect of the machine is to steal electrons from the inner lining of one Leyden Jar J, and transfer them to the lining of the other till one is highly negative and the other highly positive On HH being brought close together again, a crackling spark discharge takes place between them, while the electrical balance is being restored in the jars

ARTIFICIAL AND NATURAL LIGHTNING



G. P. A.

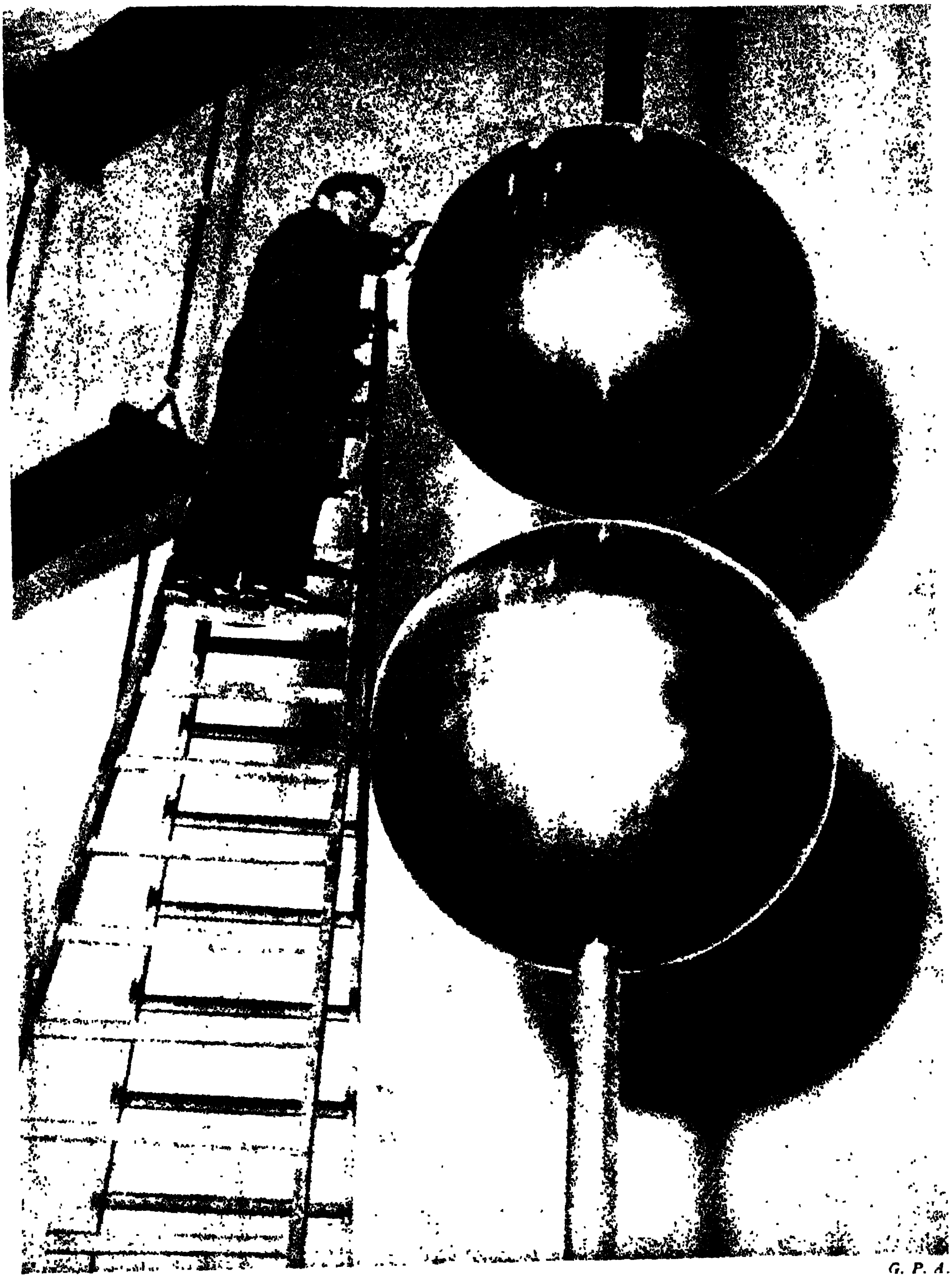
This flash of artificial lightning occurred in a laboratory. It is about 14 feet long, and to create it a tension of 2,200,000 volts was needed. The shadows of the great balls and their supports are thrown sharply on to the wall behind.



H. J. Shepstone

But the greatest flash ever produced by man's agency is insignificant in comparison with the displays given by Nature. How extensive a really fine lightning flash is has been recorded here by the camera, which can capture what evaded the human eye

BIG SPHERES FOR BIG EXPERIMENTS



G. P. A.

In this picture we get a close view of the spherical electrodes seen on the opposite page. They are the terminals between which electrical discharges take place in the course of experiments with very high tension currents. Their size may be judged by comparing them with the man on the step-ladder.

balance is restored. But as the whole operation occupies perhaps only a millionth of a second, one seems to see but a single spark during a discharge.

Some Wimshurst machines have many pairs of plates, and are what may be called electron-pumps of great power. When they are in action they produce streams of sparks a foot or more long, and a deafening noise. A spark from one of these monsters would have very serious, if not fatal, effects on any living creature.

Nature's Fireworks

But Nature, as a spark-producer, puts all human inventions completely into the shade. If during a thunderstorm two clouds, one overcharged and the other undercharged with electrons, come near each other, there is a terrific exchange between them, seen as a flash of lightning, and followed by a clap of thunder. Sometimes the discharge takes place between a cloud and the earth; and a steeple, house, or tree through which the current flows may be destroyed. Lightning sparks are to be measured not in inches or feet, but in hundreds of yards.

G P A

FIREWORKS ROUND AN INSULATOR

An enormous electrical pressure was needed to cause this discharge between points at the top and bottom of this many-storied insulator, which is under test

The Mysterious Stone

Probably 1,000 years at least before the Greeks noticed the peculiar behaviour of rubbed amber, the Chinese, who were advanced in science while Britons were still savages, made the discovery that a certain kind of stone had the property of attracting iron, and that a splinter of it, floated on water, turned north and south. In other words, they had discovered natural magnetism and the mariner's compass.

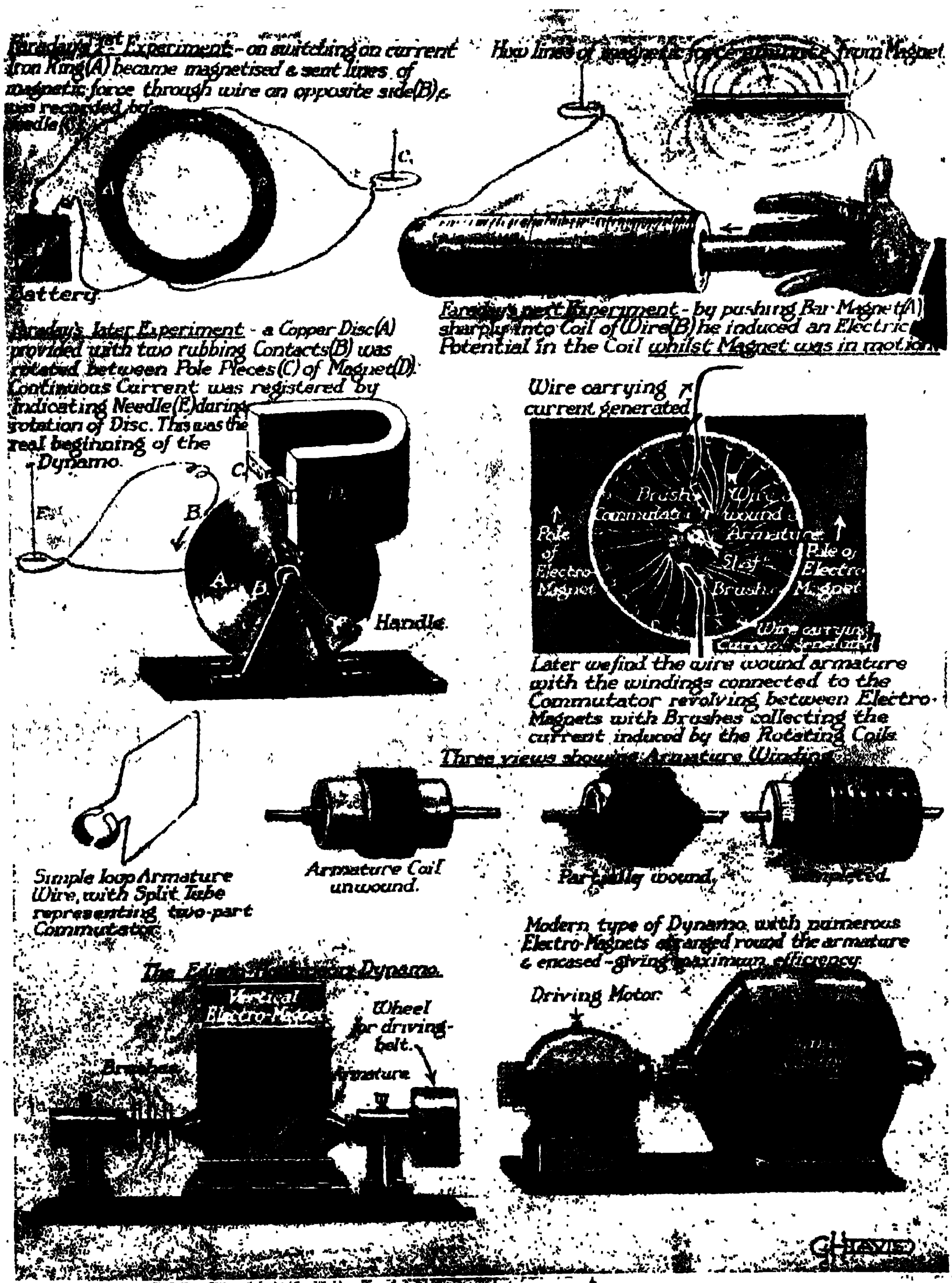
The "stone" in question is a kind of iron ore called magnetite by us, and lodestone, that is, "leading-stone," by our ancestors. Long ago it was mined at a place named Magnesia, in Thessaly, and so it came about that a steel needle or bar which has been given the properties of lodestone by being rubbed against it, or in some other way, is known as a magnet.

A magnet does not give out electricity, but, as we shall see, it has a very important connection with it.

Fountains of Electricity

Electricity produced by rubbing is of little practical use, being very unmanageable, and

HOW WE GOT THE DYNAMO



Specially drawn for this work.

The great machines used in power stations to supply us with electricity are the result of discoveries made, rather more than a hundred years ago, by Michael Faraday in connection with magneto-electric induction. This term means the creation of current in a circuit by moving part of it through a magnetic field, or by moving a magnetic field through it. Our artist here explains, by a series of sketches, Faraday's famous experiments and the development of the dynamo.

escaping in a moment if given the chance. Not till about the year 1800 was a way found of producing a *steady* electric current, by means of what we call an electric cell. This has two different substances—one usually carbon and the other zinc—standing in a fluid which causes electrons to collect round one much more than round the other. If the two substances are joined by a wire, there is a steady flow of electrons through the wire until the energy of the cell is exhausted.

By Chemical Means

For a very long time this method—the chemical method—of producing currents was the only one with which electricians had to work. The electric cell is still very useful for many purposes requiring only a small current, as for working telegraphs, telephones and electric bells. But it would be ruinously expensive to apply it to tasks which used very strong currents.

Electricity has to-day become a giant which moves our trams, trolley-buses and electric trains, lights our houses, cooks for us, keeps millions of machines running, pumps water from mines, smelts metals, and does other jobs too numerous to mention.

We could never have obtained sufficient power to do all these things just by using electric batteries. The use of electricity on the present-day scale only became possible when men had discovered how to build electric generators. The story of this advance is closely bound up with the discovery of the electro-magnet. Indeed, the history of electricity is, like so many modern wonders, a story of one discovery linking up with another and leading to a big advance.

General Electric Co. Ltd.

ELECTRIC LIGHTING OF KINGSWAY, LONDON

Electricity was known and studied for many years before methods of using it for lighting were discovered. The arc lamps came first, then the filament lamps were demonstrated by Swan in 1878 and Edison in 1879. Other advances have been made since then and our modern street lighting has become almost comparable with daylight, as shown by the above photograph taken at night in London.

THE ROMANCE OF THE MAGNET

Copyright, Wellcome Historical Medical Museum

A QUEEN AND THE MAGNET

William Gilbert, court physician to Queen Elizabeth, was the first Englishman to take a scientific interest in electricity. He put forward the theory, since proved correct, that the earth itself is a huge magnet. The artist has here represented him demonstrating the properties of the magnet to his royal mistress

THERE lived in Woolwich, about 100 years ago, a shoemaker named Sturgeon. Becoming tired of stitching shoes, he joined the Royal Garrison Artillery. In his spare time he amused himself with little experiments in electricity, and one day he tried the effect of passing an electric current through an insulated wire wrapped round and round an iron bar. To his great astonishment and delight, the bar now behaved just like an ordinary toy "permanent" magnet, clinging to any iron or steel object brought near it. This discovery raised the humble ex-shoemaker at a bound from obscurity to fame as the inventor of the *electro-magnet*.

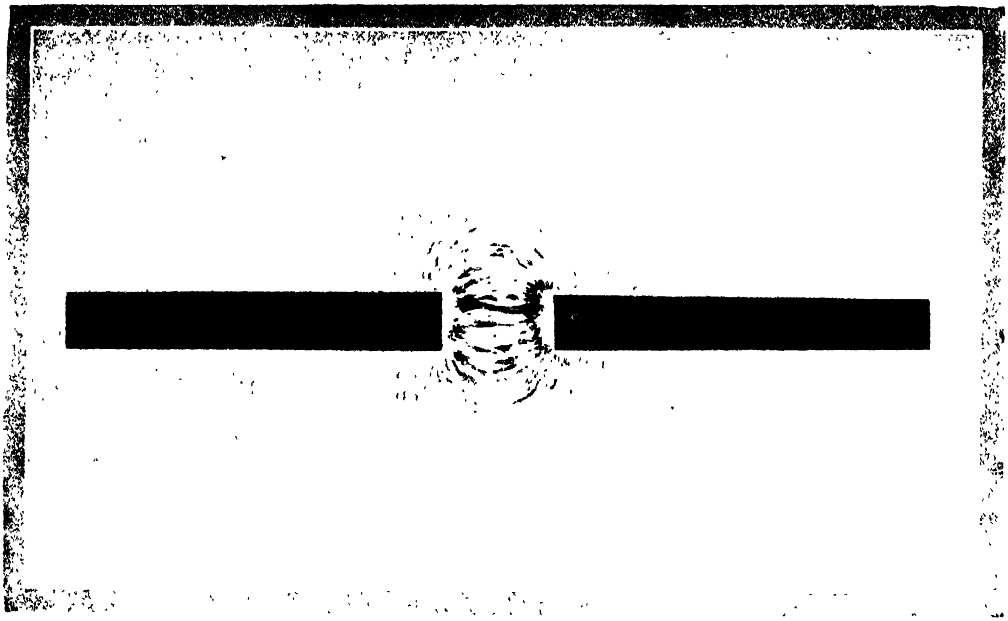
The Magnetic Poker

You can easily copy Sturgeon's famous experiment for yourself. All you need is an iron poker—all in one piece—a few yards of bell-wire, and a pocket flash-lamp battery. (Do not be tempted to use an accumulator, if you have one, as you would probably ruin it.) Wind most of the wire round the poker near the tip and connect its ends to the battery. You will then have converted the poker into an electro-magnet which will pick up needles, screws and other small iron and steel objects.

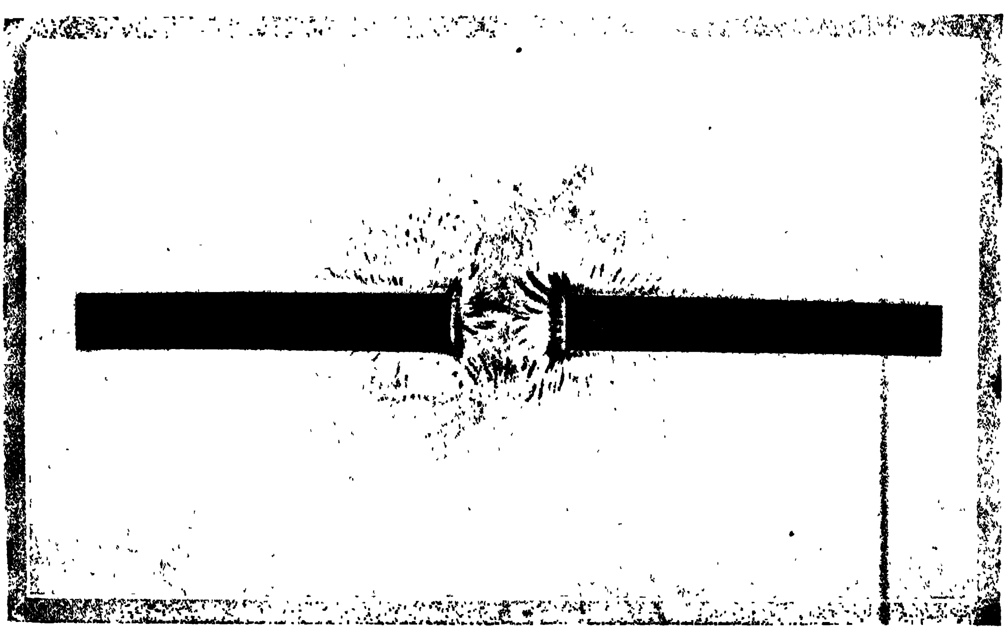
The electro-magnet is so useful to us because it remains magnetised only so long as current passes through it. It can be made to take hold or let go at will. Immediately the current is cut off, its core becomes—well, just a piece of iron.

We shall deal with some of the applications of the electro-magnet a little later, but for the moment we are

LINES OF FORCE



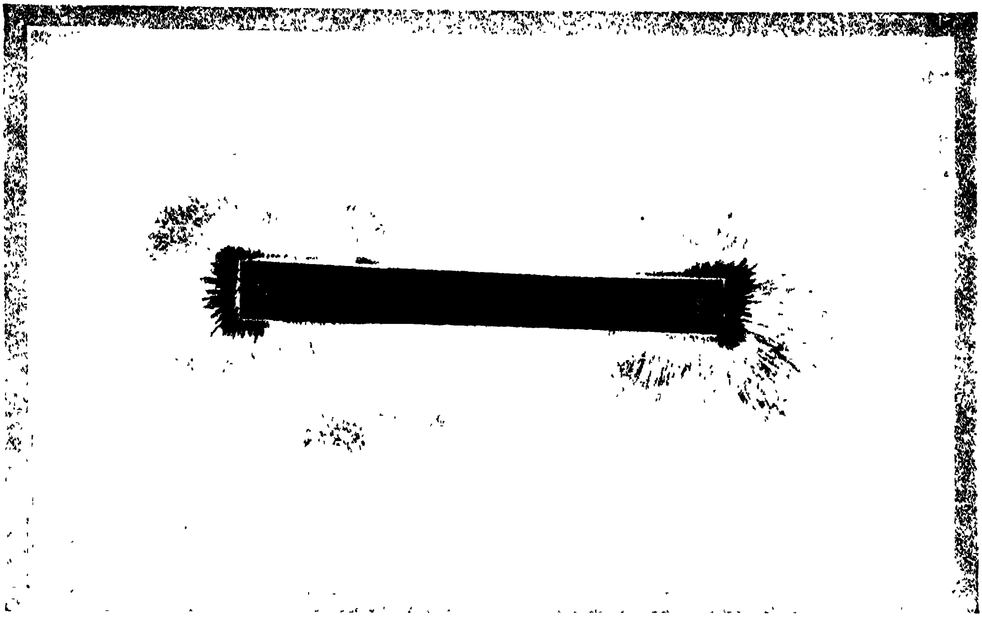
The space surrounding the poles of a magnet, throughout which the magnet's influence is felt, is called a magnetic field. Two magnets have here been laid on white paper with "unlike" poles close together, and iron dust has been scattered about. The dust arranges itself on curves running from one pole to the other.



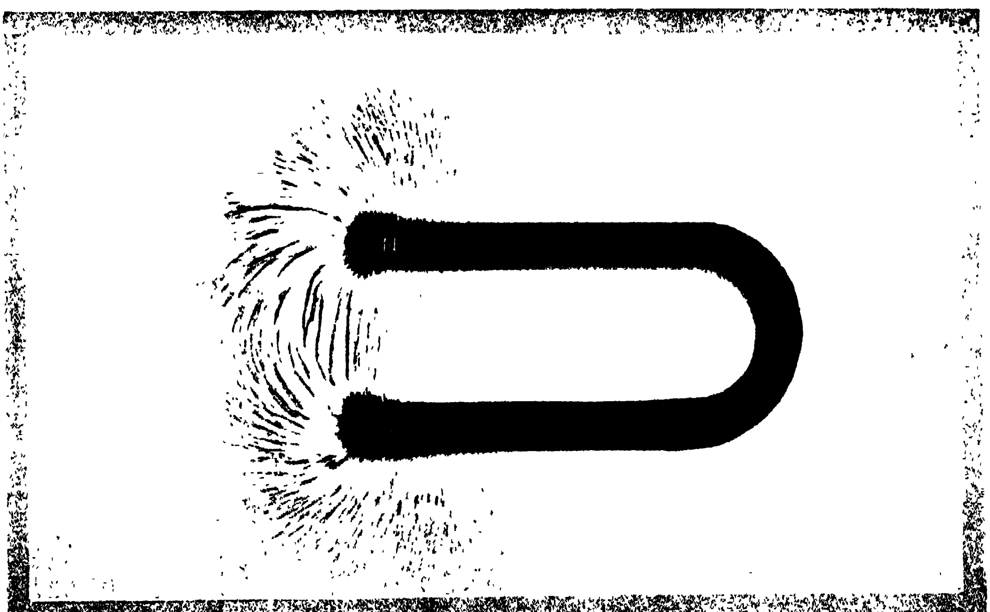
Photos: L.E.A.

The magnetic curves are called lines of force. In this second experiment the magnets present "like" poles to each other. The positions taken up by the dust show that lines of force no longer span the gap, those of one magnet repelling those of the other.

IN A MAGNETIC FIELD



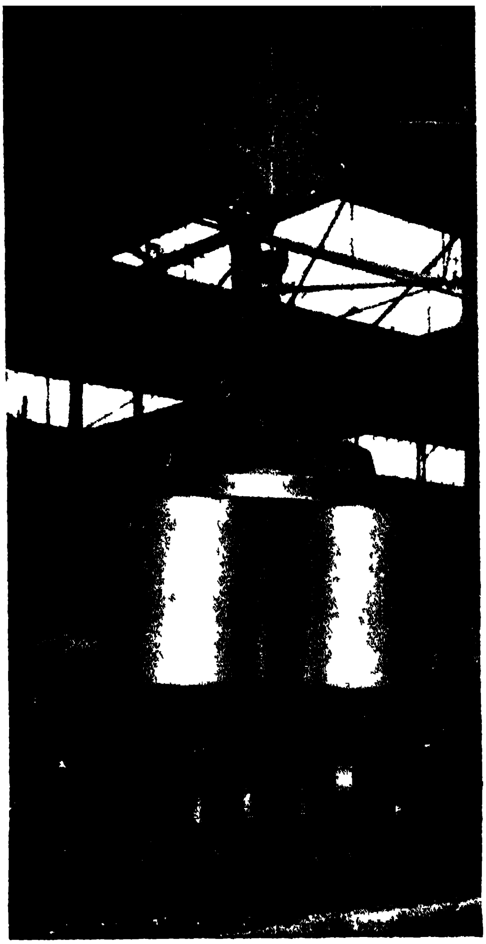
Here we are concerned with one magnet only. The lines of force are clearly visible at each pole. The dust lies along incomplete curves, each related to a curve at the other end of the magnet. The magnetic field weakens so quickly with increasing distance from the poles that the dust cannot show in full the lines running from pole to pole.



Photos: L.E.A.

The horseshoe magnet, with its poles close together, concentrates its field, and, as the iron dust reveals, the lines of force are vigorous. A metal ring moved to cut the lines of a magnetic field has a current induced in it, and to this fact we owe our ability to generate current with a dynamo.

following the story of the electric generator. Soon after Sturgeon had discovered the electro-magnet the great Michael Faraday discovered, in 1831, a fact of the utmost importance to mankind. Experimenting in his laboratory one day he found that if he moved a loop of wire up and down close to the poles of a magnet, a current flowed through the wire. The effect was much greater if a coil of wire were used instead of a loop. By studying the picture shown on p. 147 you will be able to see the steps by which inventors, using the discovery of Michael Faraday, have given us the machine called the dynamo, or electric generator. Great coils are made to revolve, by steam power or water power, between huge electro-magnets, and pour electricity into conductors, as the pumps at a city's waterworks pump water into the mains. Almost every year sees larger generators brought into use, and over 60,000 horse-power may now be drawn from a single machine.



Ігапіс Co. Ltd

A GIANT ELECTRO-MAGNET

In big engineering works electro-magnets are widely used as no special lifting-hooks and slings are required. The electro-magnet seen above is lifting two coils of sheet steel weighing nearly 3 tons.

How Electricity is Stored

When electrical engineers had discovered electric generators which would produce very large quantities of electricity they began to look round for some means by which they could store some of the electricity so that it would be ready for use whenever the generator had to be shut down for repairs or periodical cleaning In 1859, a Frenchman called Gaston Plantè discovered that if two sheets of lead were placed in a jar containing fairly strong sulphuric acid, the cell so formed had the property of storing electrical energy If a battery of these cells has current passed through it from a dynamo the electricity is " stored " in the cells and will remain there for several weeks ready for use whenever it is required.

Later on, the famous inventor, Edison, experimenting in America, discovered another type of storage battery. Instead of lead plates immersed in sulphuric acid, Edison used one plate of nickel and one plate of iron in a solution of caustic potash.

To-day, electric accumulators, or storage batteries, are used for a great variety of purposes. Every motor car is provided with a storage battery, submarines run entirely on their storage batteries, and hundreds of delivery vans use electric motors driven from storage batteries as their motive power.

Small electro-magnets are used in

MAGNETISM IN THE HOSPITAL

D.N.A.

A surgeon is here seen extracting a steel splinter from a patient's eye with the aid of a specially-designed electro-magnet. Current passing through coils inside the circular case sets up an intense magnetic field, which converts the iron bar held by the surgeon into a very powerful magnet. In most instances the magnet performs its wonderful work quite painlessly.

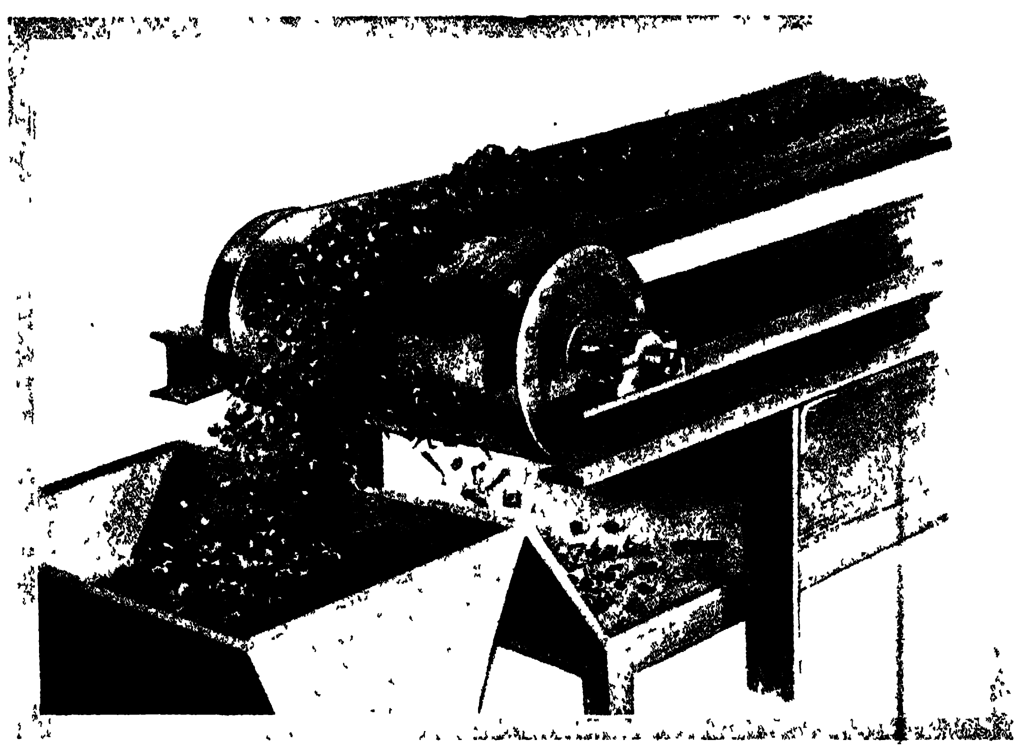
many electrical instruments, including telegraphic apparatus. We will not linger over these, but pass on to magnets designed to exert a very strong pull.

We find such magnets in the magnetic brakes of a tramcar. If the driver wishes to pull up suddenly, he moves a small lever, and magnets hanging just clear of the rails at once grip the rails with such force that the car can be brought up "all standing." Many pedestrians crossing our streets have owed their lives to these brakes.

Giant Magnets

But if you wish to see the electromagnet at its best, you should visit a steelworks or shipyard where such magnets are used for handling masses or large plates of steel and iron. In one place you may find a magnet hanging from a crane, with a huge iron ball, weighing 15 or more tons, sticking to it. The craneman touches a switch, and, crash ! the ball falls on to a heap of "scrap" cast iron below, smashing it into pieces of a size suitable for smelting. Presently the crane lays the ball aside and lowers the magnet on to the pile of broken metal. It picks up a ton or so of pieces, swings round, and, in obedience to the switch, drops its load into a railway waggon

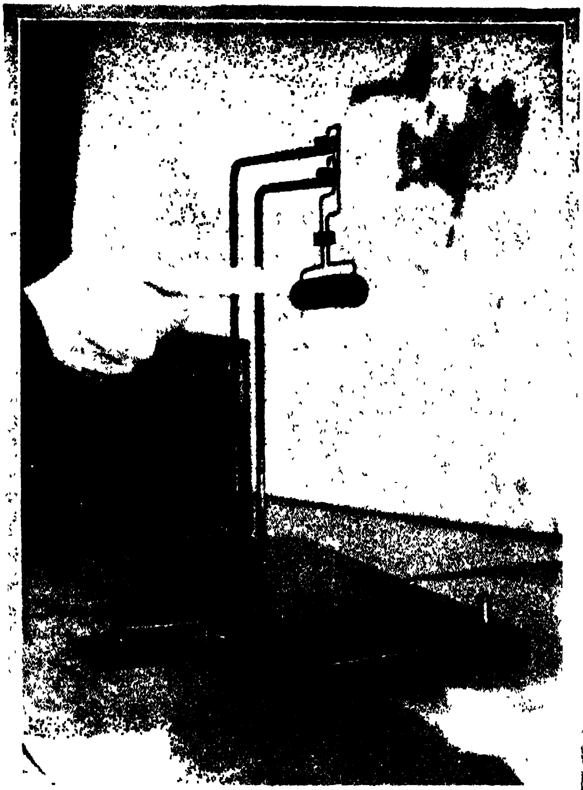
This job finished, the crane moves off to deal with a pile of 5-ton iron bars, which it raises and places where wanted with the greatest ease. Or perhaps it may be needed to unload a cargo of pig iron from a ship. The magnet and craneman between them will do in an hour as much of this work as sixty men using their hands.



Specially drawn for this work

AN ELECTRO-MAGNETIC SEPARATOR

Material containing odds and ends of iron and steel is here passing over an electro-magnetic separator, which takes the place of a pulley. Magnetic attraction makes the intruders stick to the belt, while the other material falls clear, and they are carried on underneath to a point where the magnetic pull becomes too weak to hold them up. Among other things, wheat is cleared of steel and iron objects in this manner



COIL AND MAGNET

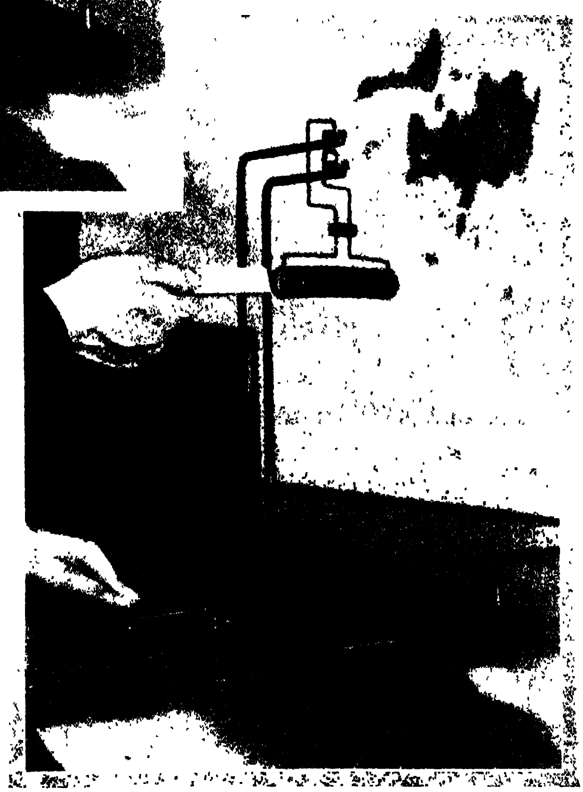
Here we see a coil of wire, the two ends of which dip into small cups containing mercury. A permanent magnet held near the coil fails to attract it—

Magnets as Surgeons

We now change the scene to a room in a hospital containing a very powerful electro-magnet with a projecting iron core tapering to a point. Two workmen from an engineering works near by come in. One has a splinter of steel in his eye, the other a chip of steel embedded in the back of his hand.

A surgeon brings the eye of the first patient close to the tip of the magnet and switches on the current. In a moment the magnet's force draws out the splinter painlessly. The other man is with equal quickness relieved of the chip, which, if left in place, might cause great pain, as the splinter might have led to blindness. Even to-day many ex-soldiers of various battlefields have pieces of shrapnel shell in their bodies, and such splinters may in many instances be extracted by electro-magnet.

In these and several other ways, such as recovering iron or steel from the bottom of a river, removing bits of iron from wheat before it goes to the grinding rolls, or separating nails and screws from workshop rubbish, the electro-magnet is a very useful servant.



Now the tapping key has been closed so that current is flowing through the coil which swings round so that one end faces the magnet pole. The current has made the coil into a magnet. Upon this simple fact depend all the electric generators and electro-magnets in use to-day.

The Friendly and Unfriendly Magnets

Magnetise five sewing needles holding them together by the points and drawing the north pole of a permanent magnet several times along them towards the eye. The magnet must be brought back through the air after each stroke, *not* rubbed up and down.

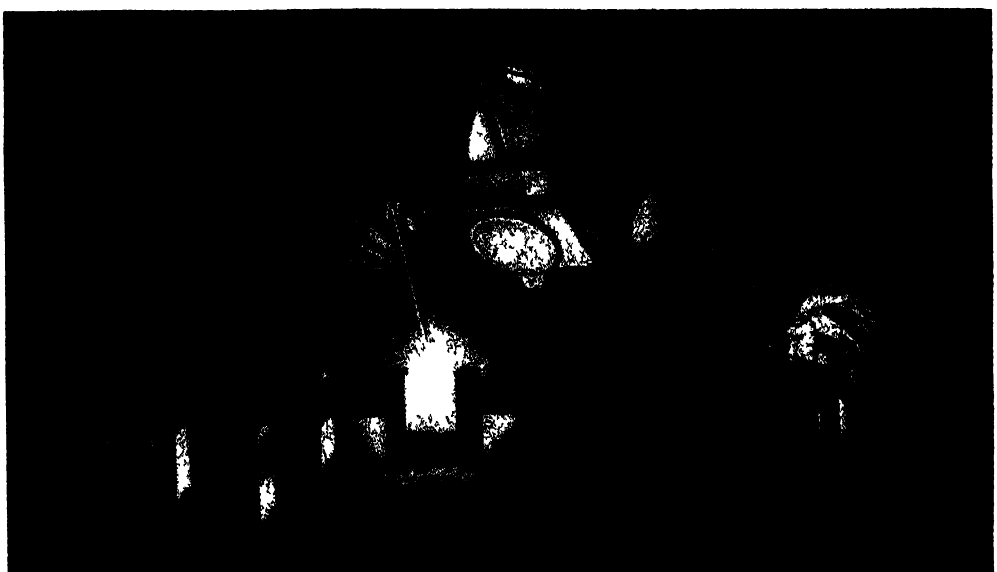
Five more needles are treated in the same way with the south pole of the magnet.

Next cut ten thin discs out of a wine cork and stick the needles through their centres. Stain the discs of the north-pole needles red to distinguish them, and dip needles and disc into thin varnish and dry them.

Drop the north-pole needles into a basin of water, eyes upwards. They at once separate, and nothing can persuade them to remain together. Then drop in the south-pole magnets, also eye upwards. They will at once take north-pole partners, for "like poles repel, unlike poles attract, one another."

There are other interesting experiments of this kind, as well as practical examples of the magnet's power. If your front door bell is of the electric kind, you have probably wondered what makes it ring. Here again the electric magnet produces the result. The wires from the bell-push (which is only a simple device for completing the circuit) go to the bell and the battery. When the bell-push is pressed, the circuit is completed and current flows through the coils of a horse-shoe electric magnet.

The magnet thus attracts the strip of metal supporting the hammer, so causing the bell to be struck. This metal strip is attached to a spring facing the poles of the magnet, and this spring pulls the strip away from a metal screw in the direct path of the circuit, thus causing an intermittent flow of current. The hammer thus moves rapidly off and on the surface of the bell giving the familiar ring that we all know.

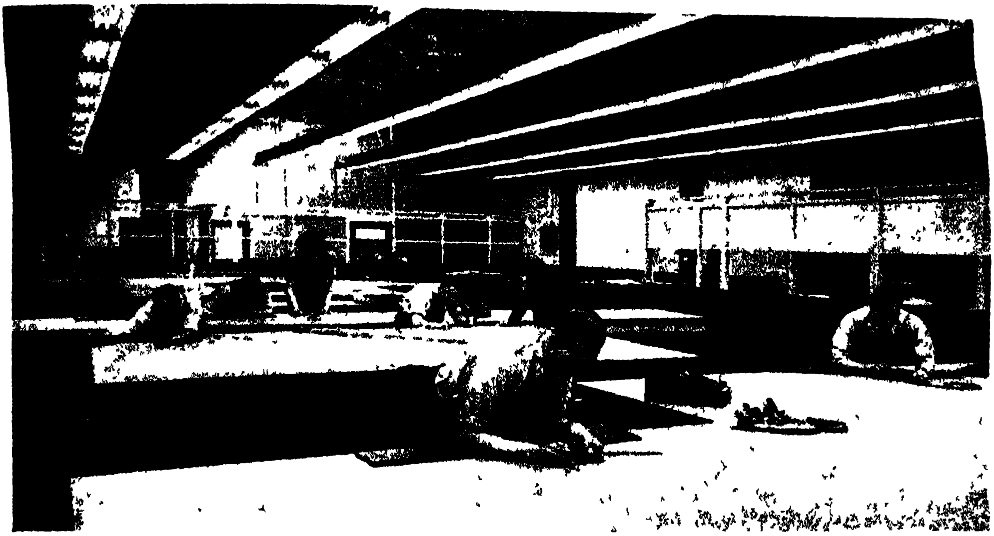


Barimar Ltd

PLASTIC SURGERY IN AN ENGINEERING WORKS

The use of electricity in industry has increased enormously in recent years Here we see an electric welder acting as a plastic surgeon in building up worn or damaged parts of an engine crankshaft by using a welding electrode to deposit a new skin of metal. When the worn part has been built up the shaft can be turned or ground to the correct size. Without this electrical surgery the shaft would have to be scrapped and a new one provided

HEAT AND LIGHT FROM ELECTRICITY



General Electric Co., Ltd

SUNSHINE LIGHTING IN THE DRAWING-OFFICE

The history of human efforts to conquer darkness by means of artificial lighting showed remarkably little progress between 2,500 B.C. and A.D. 1800. Then from the age-old oil lamps and candles came the change to gas and later to electricity. An example of modern fluorescent lighting in the drawing-office of an engineering works is seen in the photograph above.

A LUMP of coal has in it a certain amount of energy, that is, the power of doing work of a particular kind, though it does not look as if it had. But burn it, and its energy is set free.

The energy at once takes another form—that of heat. The heat may be used to raise steam. The steam, say, works an engine, a large part of its heat being used to turn the shaft of the engine and its flywheel. Some heat is thus changed into a third form of energy, the energy of mechanical motion. Nor need the changing cease here; for, if the engine be set to drive a dynamo, its mechanical energy is converted into electrical energy. This in turn may produce a fifth form of energy, that which we call light.

Many Kinds of Energy

So we can have a whole string of changes; chemical energy into heat energy, into motion energy, into electrical energy, into light energy.

The changes need not always follow this order. Motion energy, for example, can be turned into heat. Rub a pencil hard with your handkerchief, and place it against your cheek. It will feel warm. Your effort as a machine has produced heat.

Now, though one kind of energy may be turned into another, there is sure to be some wastage in the form of heat, which always makes its appearance when resistance has to be overcome. Part of the work of the engine is squandered as the heat of friction at the bearings and other rubbing parts. Then the change into electricity at the dynamo cannot take place without the heating-up of the magnets: more waste as heat. And when the electricity is sent through a conductor, some of its energy is again changed into heat by the resistance of the conductor to its passage.

This last wastage, though a nuisance in some ways, is useful in others. It may be encouraged and turned to account. If at any point the conductor be made smaller, or a special kind of

wire be used instead of copper wire, the resistance—and the heat as well—will there become greater.

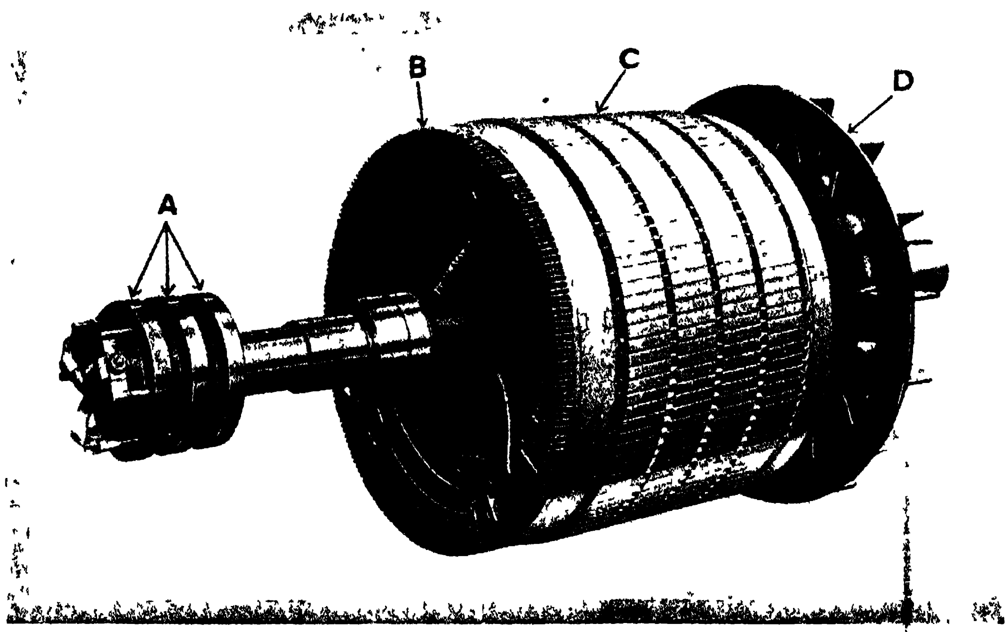
Progress in Lighting

When your grandfather went to school the class-rooms were probably illuminated by gas passing through what was called a fish-tail burner. The naked flame, yellow on the outside but with a dark centre, assumed the shape of a fish-tail and flickered a good deal. This was improved when the incandescent mantle was fitted.

You, in your days at school classes in dull weather and after dark, will have the benefit of electric light coming to you through a vacuum bulb containing metal filaments. Even this is now being improved upon. many schools and other places where a good light is of the first importance, are being equipped with fluorescent lighting, the nearest approach to day-light and noon-day sun we have so far reached.

Fluorescent is perhaps not a very happy choice of a word It comes from fluor, the name of a mineral; and fluorescence is strange, blue rays given out from certain substances when sun-shine reaches them. In a fluorescent light the material used is placed inside a long glass tube so that it glows and sends forth steady radiance when it is excited by an electrical current, though the tube itself contains no continuous wires.

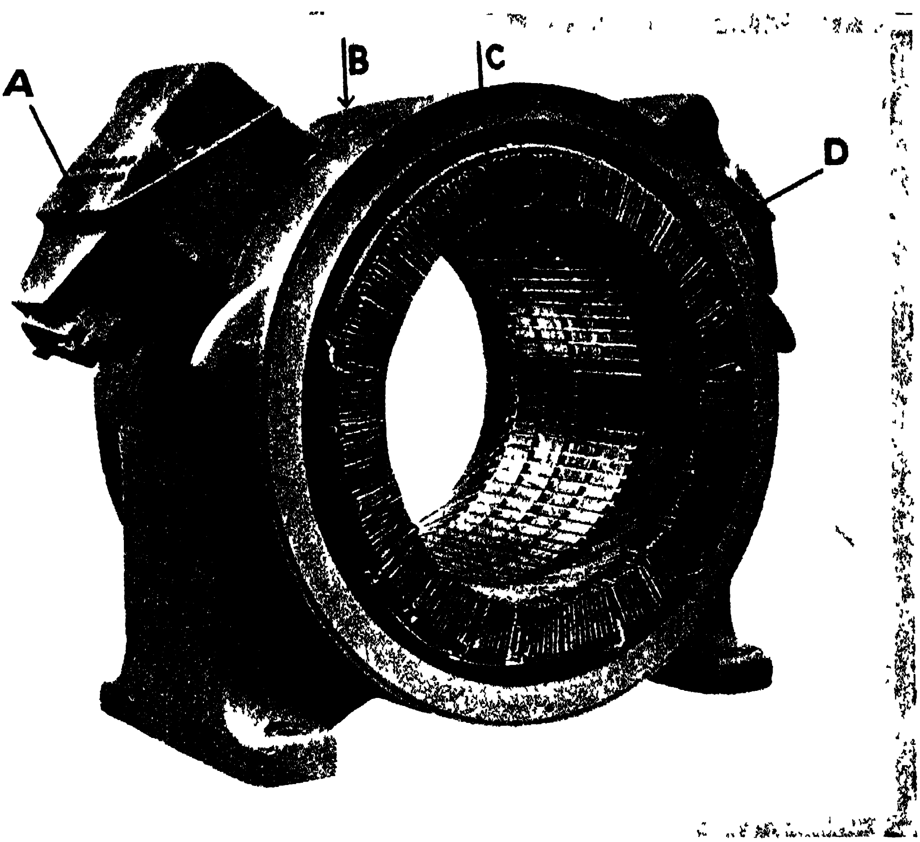
Actually, the material chosen is a chemical powder obtained from a curious earth called Willemite found on the continent of Europe There is a range of these powders, each of which gives a different shade of light, but, by a careful mixture, the light nearest to sunrays can be produced On the other hand, with varying mixtures, the deepest reds or blues, such as are



General Electric Co., Ltd

THE PART THAT DRIVES

This is the rotor or revolving and driving part of an alternating current "induction" motor The drum C is built up from a large number of steel stampings clamped side by side and slotted right across to take the coils B of the rotor winding The fan D forces cooling air through the rotor, and the slip-rings A connect the rotor through brushes with devices used in starting and varying speed.



General Electric Co., Ltd.

THE PART THAT STANDS STILL

The rotor turns inside a stationary part the stator, whereof B is the frame, and A the box through which connection is made with the electricity supply. Its winding C—the primary winding of the motor—is held in slots in steel stampings D The stator winding is not connected in any way with the rotor winding Current creates a "revolving field" in the stator, and the rotor derives its driving force from compulsion to chase this.

needed in advertising signs, are obtainable.

Wireless Electricity

It may be said that this new fluorescent system is related to Neon lighting, in which electrical current is discharged through a gas or vapour, whilst the wireless valve has also contributed to its discovery. We shall understand the matter far better, however, if we visit a factory where fluorescent fitments are manufactured and so see some of the processes for ourselves.

Let us imagine we have just arrived at such a factory. At the starting point of our tour we shall see first of all large numbers of tubes of thick, clear glass 1½ inches in diameter and 5 feet in length. We learn that these tubes begin in a cauldron of molten glass from which they are drawn through the nozzle of a machine like lead piping and in unbroken lengths. When the glass has cooled it is cut up just as required for the lamp tubes, save that a little bit extra is allowed for the finishing process. In weight, each of the tubes would turn the scale at about 1 lb.

When we arrive an operative is testing these tubes and smoothing off the ends before washing them in running hot water to remove dust, and standing

them on their ends to drain. Meanwhile, we are shown some of the fluorescent powder, exactly as it has been ground in the mills, and we wonder how such a fine flour-like substance can ever be spread evenly round the inside of a glass tube.

In the next department, however, we see some of the tubes upright in a machine, their tops closed in and their bases fitting tightly over what is best described as a bung, or valve. Soon, under the force of compressed air, a creamy solution comes surging up the tube, to flow back again when power is cut off and we observe that the whole interior of the tube has been coated as though with a brush. As for the solution, it has contained the powder, mixed with resin and spirit, the former being the carrier and the latter the solvent, to help in getting rid of the resin.

With Collector Plates

We realise at once that only the powder is wanted and are interested to see carrier and solvent removed in a gas-heated appliance, the next step being to fit a coiled filament electrode at each end of the tube, both electrodes having collector plates though they are not connected through the tube by wires. It is of the utmost interest, too, to watch some of the other processes, such as the closing, shaping and annealing of the ends of the tubes; the insertion at low pressure of a very small quantity of the gas argon to start the electrical discharge; and of a "blob" of mercury to help in producing ultra-violet rays. The air has also to be exhausted to form a complete vacuum.

Metal caps have next to be fitted at each end and a thorough test made before the finished article goes on to the packing room. Even this work calls for ingenuity, each tube being protected in a sleeve of corrugated cardboard before it is placed in its box.

What happens when the tube is fitted to an electrical circuit and the current switched on must next be explained. First of all, the wires of the electrodes are coated with a material which emits electrons freely directly it is

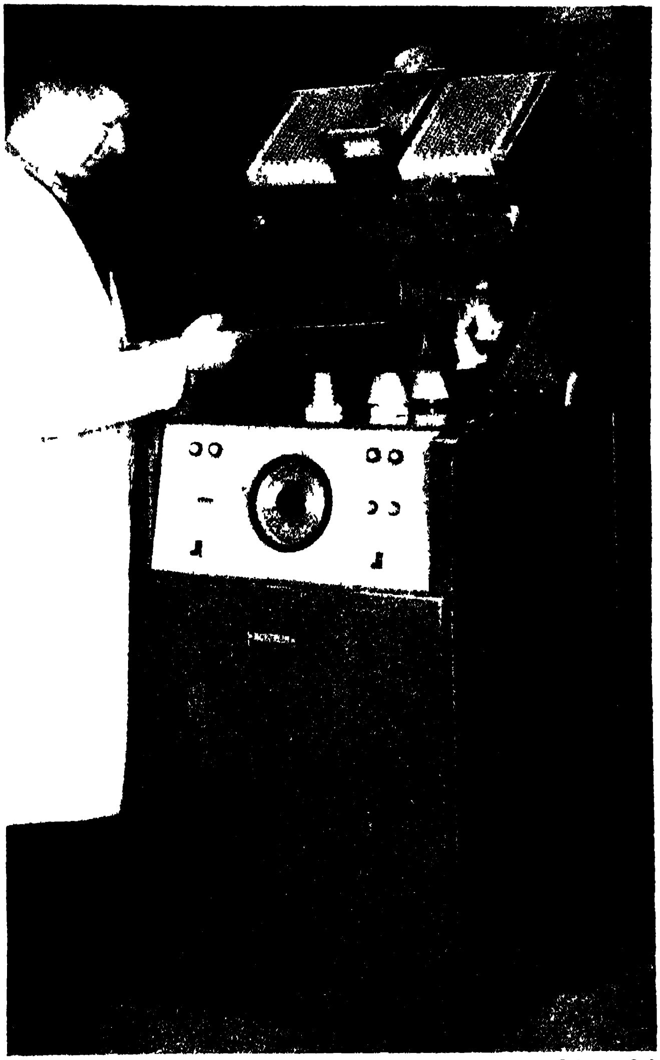
British Thomson-Houston Co, Ltd

MAKING ELECTRIC LAMP BULBS

Until fairly recent years electric light bulbs were hand blown, but to-day they are made automatically on complicated Westlake machines turning out up to 100,000 bulbs in 24 hours A human hair is half as thick again as the 0 0016-inch thick filament wire of a 100-watt lamp, and not more than 2½ per cent variation is allowed

heated. Thus, in about two seconds the electrodes are a cherry red and the ultra-violet rays cause the fluorescent powder near the ends of the tubes to glow, and finally to light up over their entire surface as busy electrons jump from one electrode to the other.

The ordinary electric light supply is used for fluorescent tubes, leads being taken to each end of the lamp. Switching on in the usual way, there is within the mechanism a starter device with a small heater coil which cuts out when sufficient warmth has been conveyed to the electrodes. There is also a choke because, though the lamp takes all the available current to begin with, less voltage is required directly the lamp warms up to its full lighting capacity. To allow for this, the choke automatically reduces the flow of electricity directly the electrodes are functioning freely.



Delapena Ltd

ELECTRONIC HEATER FOR PLASTICS

Electronic heating is particularly suitable for warming certain materials thoroughly and rapidly In this photograph we see an operator placing pellets of moulding powder called "preforms" for use in the manufacture of plastics between two metal plates connected with a radio valve circuit, generating very high frequency oscillations. This method distributes the heat very quickly and evenly throughout the material.

The Secret of the Process

The secret of the whole process is ultra-violet rays coming from the electrodes. They are not visible to us, but it is they that excite the powder and cause it to give out light. In the factory we have watched many fascinating features in the routine, such as the spot-welding of the cathode assembly, the insertion of the argon gas through tiny glass tubes, the soldering of the terminals, and others too technical for description here. Now we can see the results in the test frame and learn that an 80-watt tube produces as much light as a 200-watt lamp made with filaments, so that about one-third of the electricity gives a comparable

amount of illumination. Though the fittings are more expensive to begin with, fewer of them are needed to obtain the same result and their life is longer than that of ordinary lamps.

The schoolroom is an obvious place where the most efficient lighting is essential and I daresay you can think of many others. There is the drawing office, for example, the bench at which diamonds are being cut, hospitals, the printing works and all such places where people have to depend upon their sight and concentration. In a drapery store the natural white light of these tubes enables every object to been seen in its true colours and it is important to remember that fluorescent lighting when properly installed does not throw shadows.

Generally speaking, the tubes are arranged in reflecting troughs suspended from the ceiling at such a height that the light is evenly diffused over the work in hand. It is equally possible to have a tube as a portable fitment to be moved from place to place and used in an upright or horizontal position, with or without reflectors.

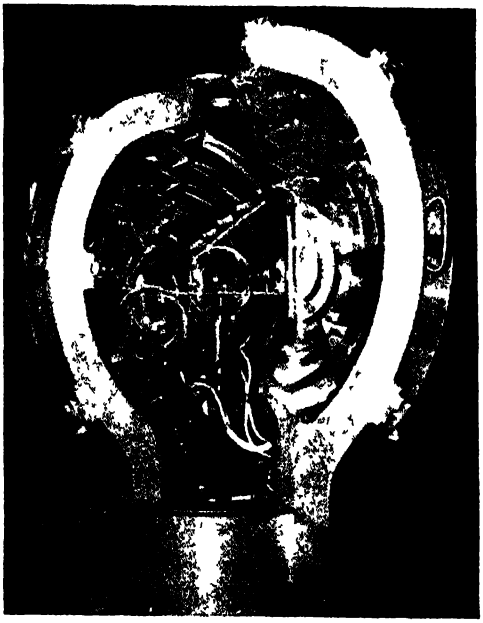
In our homes this type of lighting can be concealed behind cornices or picture rails or fixed to the ceiling or on walls in company with appropriate shades. Thus, when entering a room and operating the switch there will come almost instantaneously a flood of illumination to correspond with wonderful closeness to that of natural daylight. Apart from its pleasing appearance, there will be nothing in this form of lighting to cause glare, or to try our eyes in any way.

The principal street of New York City is Broadway, which runs north and south for thirteen miles, the whole length of Manhattan Island. It is probably the longest street in the world under one name. But it has a second claim to distinction. At night it is lit up by electric advertising signs,

General Electric Co Ltd

MINE LIGHTING BY FLUORESCENT LAMPS

The difficulty of safe lighting in the black underground tunnels of a coal-mine has been overcome in the past by different types of safety hand-lamps. Here we see a great step forward in this photograph of fluorescent lighting of roads and coal face at Chislet Colliery in Kent.



Chance Bros

TO GUIDE THE MARINER

Here we have an inside view of the optical system and single flashing apparatus of a modern lighthouse. One of the very earliest uses of electricity for lighting was in the South Foreland Lighthouse at the end of 1858

W. Brulke & Co

A LIGHTHOUSE LAMP

The first electric lights were from arc lamps and then came the filament lamp largely used in our homes to day. In this photograph we have a large modern electric filament lamp designed for use in lighthouse projectors

so many, imposing and brilliant as to make people call it the "White Way."

A good many years ago now, a huge steel erection rose on the roof of one of the Broadway hotels. It measured 70 feet in height and 80 feet in width. For a long time workmen were busy on it, and then one night its 20,000 electric bulbs began to flash, and behold! a Roman chariot race, with horses galloping madly, their tails streaming in the wind, and dust rising from their hoofs; now stumbling, now flogged into further effort by the charioteers. Ahead of the chariots, mounted men cleared the path for the racers, pressing back the crowd.

How Electric Signs Work

The illusion of motion was produced, of course, by bringing different sets of lamps into use in proper succession. In this, as in every electric sign in which the lamps are not all burning continuously, every lamp is connected with an electrically-driven switching device, called a "flasher." The most important part of this, in the case of a "living" sign, is a revolving drum, which may have pins projecting from it like those of the cylinder of a musical-box. Whenever a pin touches a flexible "brush" fixed in its path, a lamp, or group of lamps, lights up for the space of just a moment.

Heat from Electricity

One of the most useful attributes of electricity is that when it is passed through a thin wire the wire becomes hot. This simple fact has enabled engineers to construct many of the useful electric appliances which you find in your home.

For instance, the heating element of an electric iron is simply a sheet of mica with a special kind of fine wire wrapped round it. When electricity is

passed through this wire by switching on the iron the wire becomes red-hot and transmits its heat to the body of the iron.

The electric kettle is another example of the way in which we can make use of the heat produced when electricity flows through a very fine wire of special material. The electric kettle contains a heating element rather similar to that used in an electric iron.

In the case of the electric fire one can, of course, see the wires which are made red-hot by the passage of the electric current.

By using a large number of heating elements similar to those used in electric fires and arranging them inside a brick-lined chamber, engineers can construct an electric furnace suitable for melting iron, steel and other metals

Food from the Air

One of the latest uses of electric heat is its application to the extraction of nitrogen from the air. We cannot live without the food which the farmer grows for us. Nor can the farmer grow good crops unless his land be kept fertile. One of the most valuable of manures is nitrogen combined with other substances in a suitable form. The nitrogen of the air is boundless in quantity, but most plants cannot make use of it. By putting their heads together, chemists and electricians have found a way of capturing some of this nitrogen and handing it over to the farmer.

The new process makes use of the great heat which electricity will produce if applied in the right way. It is only by using electricity that we can make this particular kind of fertiliser, so indirectly, at any rate, we owe some of our food to electricity, and may be said to feed partly on air.

The Electric Smith

The intense heat which electricity can bring to bear on a small surface is now much used for joining pieces of metal together. Let us watch a man at work doing what is called "spot" welding. His job is to join two overlapping sheets of iron. He puts these in a kind of vice, between the ends of two copper bars. When he moves a switch a great current passes from bar to bar through the two thicknesses of iron, which become soft with the heat and are welded together by the pressure. The work occupies only a few moments. Plates "spot" welded at intervals are held together as firmly as if they had been riveted.

Under the Stars and Stripes

When the Americans entered the War of 1914–18, the Germans wrecked the engines and boilers of some of their big ships lying in New York Harbour. It was impossible to make new engines quickly, so electric welders were set to work on sticking the broken parts together. They cut away the metal at the edges of a break to form a V-shaped groove when the two parts were brought together, and filled this with metal melted by an electric flame. In quite a short time the ships were in service again —this time under the American flag.

The electric smith has even been turned to welding together all the metal parts of a ship's hull—plates, beams, frames, bulkheads, etc.—and has done it well, not a single rivet being needed.

Heating Without Wires

All the different heating appliances described above depend upon one simple fact. When an electric current passes through a wire which is very thin or which offers a high resistance to the flow of a current the wire becomes very hot.

The newest form of heating by electricity does not need any red-hot wires. This new form of heating is called electronic heating. An electronic heater has a table upon which is placed the substance which has to be heated. A flat plate is then placed in position over the substance and a very high-

frequency voltage is switched on between the table and the plate. A high-frequency voltage means that the electrical pressure is applied first in one direction and then in the other direction, the changes taking place perhaps a million times in a second. This has a curious effect upon any substance such as rubber, plastic or plywood, which may be placed on the table of the electronic heater. The effect is that the whole of the substance is rapidly heated right through. Electronic heating is, therefore, very suitable for very quickly warming materials such as plastic, rubber and the sheets of wood and the cement used for forming plywood.

A picture of one of the latest types of electronic heaters will be seen in these pages. This particular heater is used for heating plastic materials before they are put into the moulding press.

Compass and Magnet

A young man was once asked to explain to some ladies the working of a railway locomotive.

"Oh!" said he, "it's ever so simple. You see, the driver claps the boiler on to the fire, and the fire get into the water, and the steam gets into the wheels, and away we go!"

Hardly a brilliant effort! We wonder what he would have made of the electric motor, if he could do no better than this with a steam engine, which at any rate has a good number of visibly moving parts. The electric motor is so much more mysterious a contrivance.

However, we will do our best to throw some light on its working, in a manner that you can understand.

By way of introduction let us suppose that we have on the table before us a small pocket compass and a horseshoe magnet. On presenting one pole of the magnet to the compass needle—which also, as you know, is a small magnet—one end of the needle will at once fly towards it. We now present the other pole, and the needle promptly swings through a half-circle. By moving the horseshoe magnet quickly to and fro sideways we can make the needle spin round and round, and we

Stewart & Lloyds Ltd

SAWING WHITE-HOT METAL WHILE IT MOVES

Here we see an electrically-driven circular saw being used for cutting white-hot steel tube into required lengths as it comes from the tube mill. The saw with its motor is mounted on a carriage which moves to and fro as it cuts through the moving tube.

have an electric motor in its very simplest—and, we fear we must add, most useless—form. Its motion is due to alternate attraction and repulsion between the poles of the big magnet and one pole of the small one, the changes being made at just the right moments to keep the needle moving.

Another very interesting thing is this: If a current is passed through a coil of wire the coil becomes a magnet, and if it is hung so as to be able to swing easily it will turn north and south like a compass needle. If you reverse the direction of the current, the coil will swing through a semicircle, for its poles also have been reversed. An iron bar or core with a coil of wire wrapped round it becomes a magnet when electricity is sent through the coil. This is called an *electro-magnet*. The ordinary horseshoe magnet and also the needle of a compass are both called *permanent* magnets

Next we will get to grips with a practical motor. This has a fixed circular frame with two electro-magnets projecting inwards from it opposite to one another, and an iron drum-like part, mounted on a spindle, turning in the space between the curved ends of the magnets. The drum is wound from end to end with a coil of wire.

Friendship and Enmity

When current is sent through the magnets and the drum coil, the coil becomes a magnet too, and one end of it is attracted to each of the fixed magnets. Just as it comes into the position it likes best, the current through the coil is automatically reversed. Friendship is at once changed into enmity, and each fixed magnet demands the opposite end of the coil, spurning that nearer it. So the drum makes another half-turn, the current is again reversed, and this changing is repeated so quickly that in a few moments the drum electricians call it the armature or rotor—may be spinning a thousand or two times a minute.

The motor described, though it would work all right, would be jerky in its action, as the spindle is turned much more strongly in some positions of the coil than in others So the drum is usually wound with a number of separate coils, distributed round it, and each comes into use twice during every revolution of the spindle Then the motor pulls equally hard all the time, and gives steady motion to whatever thing it is set to drive.

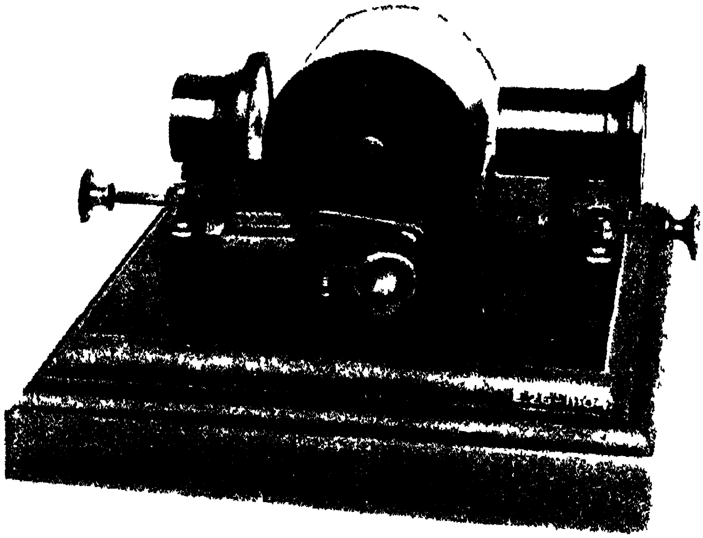
British Thomson Houston Co. Ltd

AGAINST THE BLACK BACKGROUND OF NIGHT

Flood-lighting at nightfall of historic or important buildings has been a feature in recent years of national and local celebrations Here we have a view of the Horse Guards Parade, London, illuminated by Mazda Mercury Vapour Lamps in floodlight projectors

Famous Inventions and How They Were Evolved

What Master Minds Have Done for the Good of Man



H M Stationery Office

THE FIRST MACHINE TO REPRODUCE TALK

This is the original phonograph made by Thomas Edison in 1877 The grooved cylinder in the middle, covered with tinfoil, is revolved and moved slowly endways by turning the handle On each side of it is a recorder with diaphragm and needle for indenting the foil in obedience to sound vibrations and reproducing sounds

HOW SOUNDS ARE WRITTEN DOWN

ONE day in the year 1877 Thomas Alva Edison, the great American scientist, took a sheet of tinfoil and wrapped it round a metal cylinder having a fine corkscrew-like groove cut in it from end to end. The cylinder was mounted on a horizontal shaft, cut at one end with a screw-thread of the same pitch as the groove on the cylinder. When the shaft was turned by a handle, the cylinder moved endways slowly, the groove being always opposite a sharp steel point pressing on the tinfoil.

The steel point was connected with a disc on the end of a mouthpiece. Edison turned the handle steadily and spoke into the mouthpiece. Every vibration of his voice drove the disc away from him and made the steel point press the foil more or less deeply down into the groove behind it. When the needle reached the end of the foil, it was lifted off, and the cylinder was run back into its original position. On the cylinder being turned forward a second time, with the needle touching it, the dents in the foil made the disc flutter exactly as it did when "talked at," and the original words were reproduced.

Thus, in the year following that of the invention of the telephone, Mr. Edison became the parent of a machine

by means of which, to use the words that appeared in *The Times* soon afterwards, " the old familiar voice of one who is no longer with us on earth can be heard speaking to us in the very tones and measure to which our ears were once accustomed."

Phonograph and Dictaphone

This new invention was named the phonograph—the recorder of sounds. Its tinfoil soon gave place to a hollow wax cylinder, into which a hollow-ended sapphire cutter gouged tiny depressions, corresponding in frequency to the sound vibrations shaking the disc of the mouthpiece. A phonograph record, examined under a magnifying glass, appears as a series of scoops, varying in length, depth and spacing. To reproduce the sounds a tiny sapphire ball, as large across as the cutter, is used. This falls into the depressions, and in doing so shakes a disc in a sound-box, and sets up air vibrations in a horn.

The phonograph both records and reproduces sounds. If a record be needed no longer, the wax may be shaved away deeply enough to remove the sound waves, and the cylinder can then have another record made on it. But as a means of entertainment the phonograph has practically gone out of use, because wax cylinders are delicate and rather awkward to store. A special form of it, however, called the dictaphone, is employed in many business offices for taking down letters. The dictated records are transferred to reproducing machines in the typists' office.

From the phonograph was developed the instrument with which we are familiar to-day—the gramophone.

The Gramophone Co. Ltd.

YOU WILL RECOGNISE THIS

The picture " His Master's Voice " has made this dog—a real dog that really listened—world-famous as the central feature of what is probably the most successful pictorial advertisement ever produced.

E.M.I. Sales and Service Ltd

TESTING THE RECORDS FOR WEAR

From the original wax record a copper shell, known as the Master is made and then a second record, known as the Mother, or working matrix, is taken. The Master record is carefully stored away, but from the working matrix the records to be sold to the public are made. From each batch a certain number are tested and in this photograph we see sample records undergoing tests for wear.

Many improvements in the methods of making records have been made since the early phonograph days.

The Gramophone

This cannot make records, but only reproduces them, by following with the tip of a steel needle a spiral groove in a hard, flat disc.

The groove appears smooth enough to the eye, but really it is a series of zigzags. The needle is fixed to one end of a delicately pivoted lever, the other end of which is attached to the centre of a mica or metal disc, clamped firmly round the edges in a sound-box. The tip of the needle follows every zigzag in the groove, and in doing so vibrates from side to side. The sound-box disc necessarily vibrates with it, and creates air waves which reproduce the sounds recorded.

How a Gramophone Record is Made

Thanks to the kindness of The Gramophone Company, Limited ("His Master's Voice"), we are able to give a short description of the various operations needed in the making of a gramophone record.

We will assume that Madame X., the famous soprano, is to have one of her songs recorded. The singing is done in a studio specially equipped for the purpose, in front of a microphone.

Every vibration of the singer's voice makes the microphone's disc flutter and send an electrical impulse to the stylus or cutting point of a recording machine. The last has a revolving table like that of an ordinary gramophone, on which is a circular slab of a special wax, about an inch thick. As the " wax "—this is the technical name given it—revolves, the stylus, which can move sideways only, cuts in it a groove about $\frac{7}{1000}$ inch deep and $\frac{1}{100}$ inch wide. A tiny gauge-wheel, running on the top of the slab, prevents the stylus sinking in too far.

While the table revolves once, the stylus is drawn about $\frac{1}{100}$ inch towards the centre of the " wax ". The result of the revolution of the " wax " and the sideways travel of the stylus is a continuous volute or spiral groove having 100 turns or so to the inch.

While the stylus cuts it also vibrates sideways in time with the vibrations sent from the microphone. So the path which it makes for itself is a zigzag one. If, for example, it is recording a note having 3,000 vibrations a second, the stylus will zigzag at the same rate. So one need not be surprised if even a strong magnifying glass fails to reveal the individual zigzags. One has to remember, too, that the nearer the stylus gets to the centre, the smaller is the length of groove cut in a given time, and the zigzags must be crowded closer together. Nor is it a matter of simple zigzags, for each zig-zag has in it smaller zigzags, peculiar to the particular *cause* of the sound. If it were not for what we may call these secondary zigzags, which give sounds their special *timbre* or quality, it would be very difficult to tell whether a musical sound issued from the human throat or a piano, or a violin, or what not.

The " wax " on which Madame X.'s song has been recorded is so soft that it can be

Dictaphone Co Ltd

TYPING FROM THE DICTAPHONE

One form of the original sound-recording invention has been developed as the Dictaphone for business purposes. It enables the busy man in industry, politics, and even authorship, to dictate letters, notes and chapters just when most convenient to him The secretary, as seen in the photograph above, afterwards types the letters or manuscripts from the record's dictation, the speed of which can be adjusted

E M I Sales and Service Ltd.

TO ENSURE THAT EACH RECORD IS PERFECT

Every detail of a new record is carefully tested to make certain that only a perfect record is sent from the factory to the distributor who sells to the public. In this photograph the final stage of these tests has been reached and the label on the record is finally checked to see that every detail is correct

scratched with a finger-nail, and the needle of a gramophone would ruin it immediately. So it must be copied, down to its finest details, which are extraordinarily minute, in some substance hard enough to stand the wear of many reproductions.

Through Copper and Nickel

The "wax," after being cleaned, has its face dusted with fine metal (bronze) powder, which is rubbed in by a brush revolving so fast that any excess of powder is flung off by centrifugal force. It is next placed in an electro-plating bath, and a coating of copper is deposited on the metal, which, unlike the wax itself, is able to conduct electricity. The copper coating, when peeled off, is, of course, a "negative" of the "wax," with ridges on it in place of grooves. This negative, known as the "master," is preserved very carefully.

Coated with Nickel

The "master's" face is first coated with nickel—a much harder metal than copper—to protect it against damage, and then with a solution which prevents sticking, and goes into the copper bath. The deposit of copper on it (peeled off when thick enough) forms a positive record, exactly similar to the "wax." This copy is named the "mother" of the record. From the "mother" are made any required number of negative nickel copies, each called a matrix, by electro-plating. These, when stiffened by a backing of thick copper, serve as the dies which mould the record finally as a positive in hard material.

So you see that a record is well guarded in manufacture. If a matrix be damaged, a new one can be taken from the "mother." If the "mother" itself suffered injury, a new mother could be made from the "master."

Moulding a Record

A record which you buy for your gramophone is composed of lamp-black, shellac, copal, and other substances. The various ingredients are ground up very fine, well mixed, and pass again and again through mills heated by steam. The heat makes the mixture plastic. It is rolled out into a continuous sheet, a yard or so wide, grooved lengthwise and crosswise so that, when cold and brittle, it easily breaks up into pieces each containing enough "biscuit" for the making of one record.

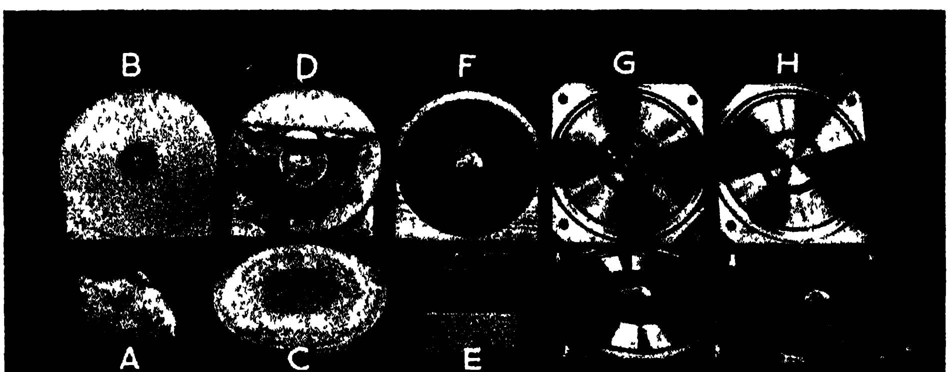
In the pressing-room of the factory are enormously powerful presses, able to give a 70-ton squeeze. A matrix of one record is fixed firmly, face upwards, to the lower plate of a press, and that of another record, face downwards, to the upper plate.

A Piece of "Biscuit"

The highly-skilled pressman lays a label face down on the lower matrix, and another label face up round a pin projecting through the top matrix. He then takes a lump of soft disc material—a piece of "biscuit" heated up—adjusts it in the centre of the lower matrix, closes the press, and turns on the power. The dough is squeezed out flat, with impressions of the matrices on its two sides, and is almost immediately cooled and hardened by water circulating through the press. The press opens, and out comes a "double-sided" record, finished except for the polishing of its edges, which is done on another machine.

Reproducing by Electricity

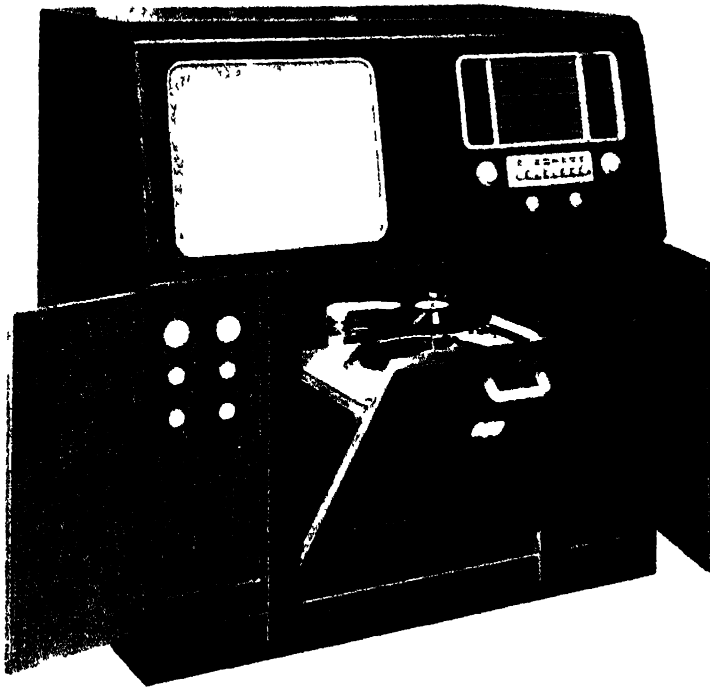
Every record is examined many times over for various possible defects, some of which go by the names of "drags," "dips," "pimples" and "bumps." If it gets safely through its examination, it is carried off by a conveyor to a vast store, containing many miles of shelves on which there is room for millions of records all arranged most systematically.



The Gramophone Co. Ltd.

THE STAGES OF RECORD-MAKING

A is a lump of the special material used in making an original record, a "wax," which in B is seen ready for recording C shows the "wax" after recording, the wax shavings produced by the cutter are now removed by suction as it is cut In D an electrically-deposited copper copy is being stripped from the "wax." E is the material, in its powder form, used for making F, a finished record The matrices for two records are in the mould plates at G and in H have pressed a record



The Gramophone Co Ltd

A COMPLETE ENTERTAINMENT PROGRAMME FOR THE HOME

Edison, Marconi Baird, are the names of three men whose pioneer efforts made possible the magic box shown above The gramophone is a ten record auto changer, with push-button controls seen on the left Above this control panel is the screen which brings all the Television broadcasts sent out by the B B C, while on the right is the 5 valve super het radio receiver for listening to the wireless programmes from home and overseas stations

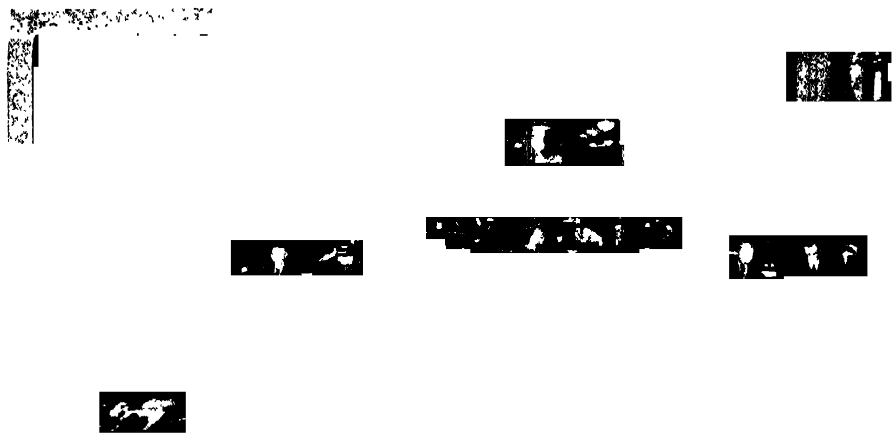
Some gramophones make use of a device called an electrical pick-up for reproducing records. Instead of shaking a disc in a sound-box, the needle vibrates a small body of iron between the poles of an electro-magnet. The vibrations set up currents in the magnetic circuit, and these are magnified by wireless valves and converted into sounds by a loud-speaker. A gramophone of this kind ca conveniently be combined with a wireless receiving set.

By moving a switch, the record pick-up circuit is cut out, and the wireless receiving circuit connected with the valves ; or the other way about.

Before the end of 1939 this combination of gramophone with a wireless receiving set had become increasingly popular, but manufacture ceased during the war years. The advantages of such a set are obvious as the sound reproduction of a good wireless receiver is as near perfection as modern science can make it. Now that television is with us again after its temporary banishment we have another important item on the home entertainment programme.

With wireless and television programmes before them, a good selection of gramophone records at hand, and with a modern instrument designed to give the best results from any one of the three in turn, merely by changing a switch or turning a knob, the modern family need never be bored because of lack of entertainment ! As our illustration shows, all three forms of entertainment are now available to them from the one cabinet.

MESSAGES AND PICTURES BY WIRE



Post Office.

IN LONDON'S CENTRAL TELEGRAPH OFFICE

Some idea of the great number of telegrams sent from a big business centre can be gained from this photograph taken in the main office of the telegraph service in London. Roughly two-thirds of all telegrams sent in this country are business messages and one-third social messages. Less than 2 per cent. contain bad news while 4 per cent. are congratulatory

As in every other department of Science, progress in all branches of electrical engineering has been not merely rapid but almost revolutionary in the past fifteen or twenty years. This is particularly true in the field of telegraphic communication. Instruments and methods which were described as modern less than twenty years ago are already museum pieces.

The first practical electrical telegraph was produced in 1837 when Cooke and Wheatstone in England brought out the needle telegraph while in America Morse produced his electro-magnetic telegraph. From these inventions standard instruments were developed and used in different types of work.

For nearly a hundred years the Morse code was employed for the transmission of messages by telegraph. The sender at one end tapped a pivoted brass lever in front of him and so caused an electrical contact of brief or not quite so brief duration which resulted in a series of dots and dashes being recorded at the other end.

The message thus tapped out was received at the other end by an inking device which recorded the dots and the long and short dashes; this was decoded and the message written out in plain language for the person to whom the message was being sent. There were other types of apparatus which punched holes in the paper tape, which was then put into an automatic typewriter (Creed) and the message printed in clear words for all to read.

Fairly early in the history of the telegraph Professor D. E. Hughes invented an apparatus for delivering messages directly in printed type. At the sending end was a piano-like keyboard with twenty-eight keys on each of which was a letter of the

SENDING AND RECEIVING TELEGRAMS

Post Office

The Teleprinter is now established in all large Post Offices for the sending of telegrams As will be seen from the photograph it is similar to a fairly large typewriter and the keyboard is operated in much the same way On receiving a signal the operator switches over the instrument to the receiving position and the message is printed on paper tape or, in some machines, on a roll of paper, exactly as typed at the sender's end This message is pasted on the official form and is ready for dispatch to the addressee.

alphabet or other character. The receiving apparatus had a typewheel with twenty-eight characters on it. If key A were pressed down, the receiver printed A on a paper strip. The chief difficulty at first was to keep things in step but this was eventually overcome.

From this machine developed the "Tape" machine, so named because it prints on a long paper tape. It has been in use for many years in stock exchange offices, business houses and clubs as well as newspaper offices for receiving the latest news.

From Morse to Teleprinter

A few years before the Second World War the telegraphic system in British Post Offices was completely reorganised. Up to the year 1935 various types of apparatus were in use in different offices from the "dot and dash" Morse sounder machines to the punching machines already described, as well as the Hughes piano-keyboard transmitter.

To-day the Teleprinter has replaced all other instruments and has been installed as a general rule in all Post Offices where 150 or more messages are handled daily. Smaller offices accept telegrams but they are immediately telephoned to the nearest Teleprinter office from which they are dispatched.

The Teleprinter, as will be seen from the photographs, is very similar in appearance to a large typewriter and has very much the same keyboard. It is slightly different in "touch" compared with a typewriter owing to the fact that the Teleprinter is electrically operated. Each time a key is depressed an electric current comes into operation and many miles away a similar Teleprinter apparatus, switched over to the receiving position, types out the letters, figures, and spaces, as the distant operator types them.

In some of the Post Office machines the message is printed on paper tape, as in the photograph on page 175, but in others the message is typed direct on to a roll of paper. The tape can easily be torn or cut into small pieces and pasted on the official telegram form; the portion on the roll containing the message just received can also be easily torn off for similar treatment.

Signals are exchanged between the operators at each end so that one knows when a message is to be received and when it ends, while the sender learns that it has been correctly received. As the Teleprinter has a typewriter keyboard, works up to 65 words a minute, and prints the telegram ready for delivery, its advantages are obvious. It is believed, too, that operators working Teleprinters are able to retain a high degree of manipulative skill until a much later time of life than was generally possible with the morse-key working.

Under the G.P.O. "Telex" system Teleprinters can be installed in the offices of big commercial companies so that they can communicate direct with their branches or with other users of the "Telex" system, or direct with the Post Office telegraph office.

The use of private wire teleprinter circuits by commercial and other large concerns has increased rapidly during the last few years and a large number of circuits, both single and in groups with switchboard facilities, were installed by the Post Office.

Working Without Strain

It is worth mentioning that the Post Office attach great importance to the training of their staff to make sure that those who will operate the Teleprinters acquire the right touch and correct rhythm. A well-trained staff works accurately and easily and without any sense of strain. A special telegraph training-school is run by the G.P.O. to give newcomers thorough training before they tackle the real thing.

For special occasions the Mobile Post Office comes into use. This is really a

HOW THIS BOOK WAS BUILT

Photo By courtesy of the Century Engraving Co

In a work such as *Pictorial Knowledge*, where so much depends upon the many hundreds of illustrations, the printing blocks are of the highest importance These blocks consist of a metal plate mounted on wood to the height of the type, and in this photograph we see an etcher preparing the plate for an acid bath He is protecting with an acid-resisting varnish those parts which are not to be etched

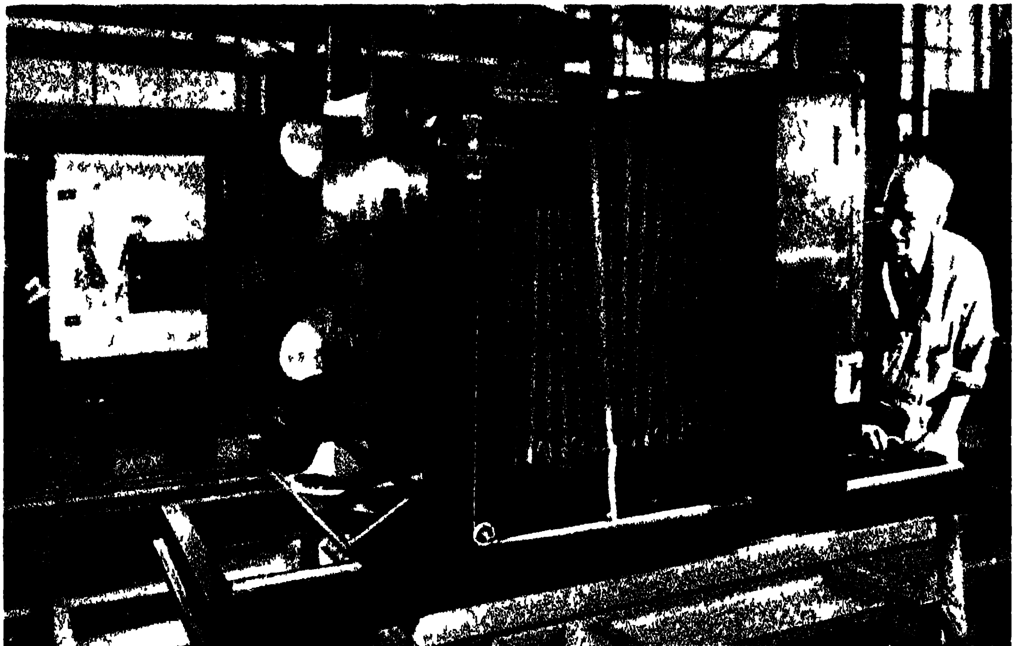


Photo. By courtesy of the Century Engraving Co

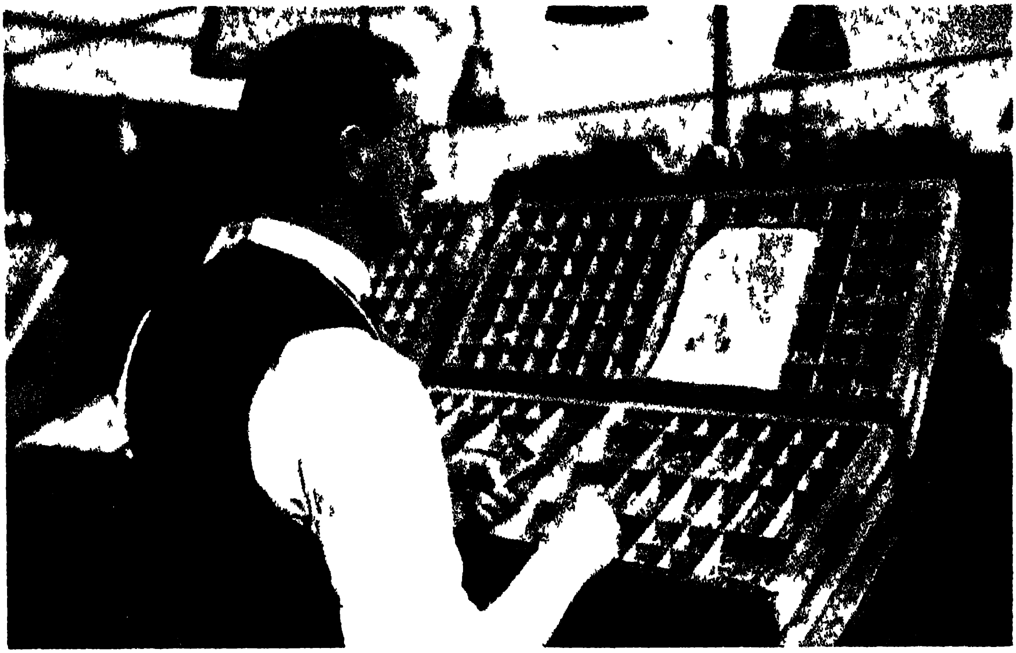
Here we have the camera used for taking a photograph of the illustration to be reproduced For printing purposes the picture is reversed through a prism, but, before the exposure is made, the image has to be adjusted on a ground-glass screen to the correct size From the negative the image is transferred to a metal plate, which, after chemical treatment finally evolves as a printing block.

Photos By courtesy of the Whitefriars Press, Ltd

The letterpress in these volumes was set up on a Monotype machine Here you see the keyboard which has 276 keys These keys punch holes in a roll of paper ribbon

The ribbon is transferred to this machine, known as a caster By means of the punched holes the letters and signs are selected and the type comes forth in units ready for use

A COMPOSITOR SETTING UP TYPE

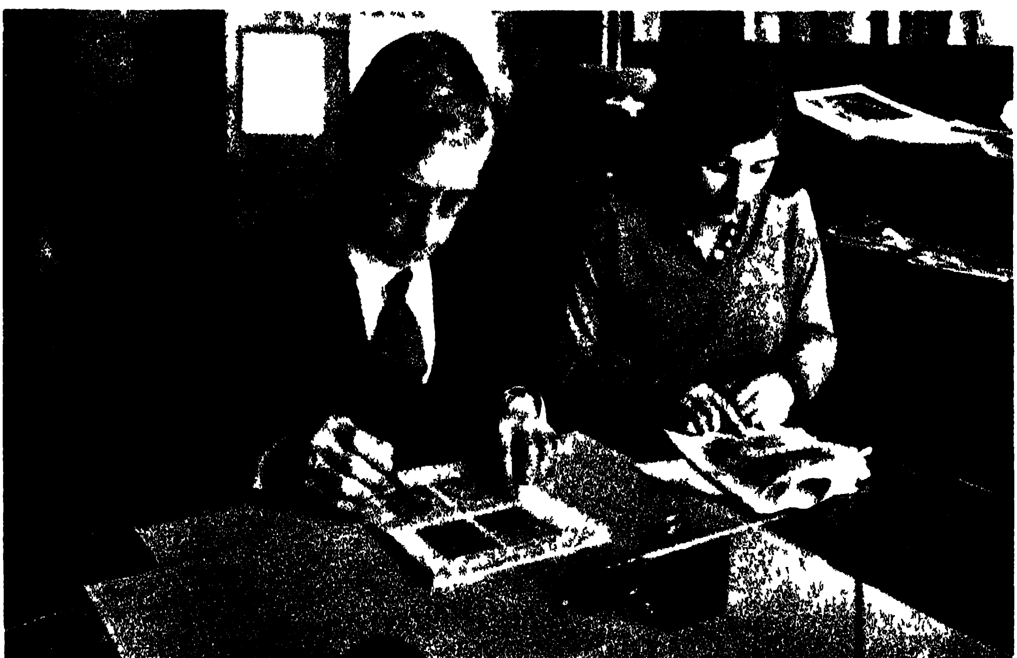


Before the days of the Monotype and Linotype machines all type had to be set up by hand, but in these volumes only the chapter headings are done in this way In the illustration above a compositor is seen at his work selecting the letters required for a heading His upper case contains the capitals small capitals and figures while in the lower-case are found the ordinary letters and spaces

Photos By courtesy of the Whitefriars Press Ltd

When a long length of type has been set up—sufficient for about two columns—it is placed in a metal tray known as a "galley" and a proof is taken with a hand-press William Caxton, who first brought printing to England and set up his press in Westminster in 1477, used a crude sort of hand-press for the same purpose to produce the earliest printed books in this country

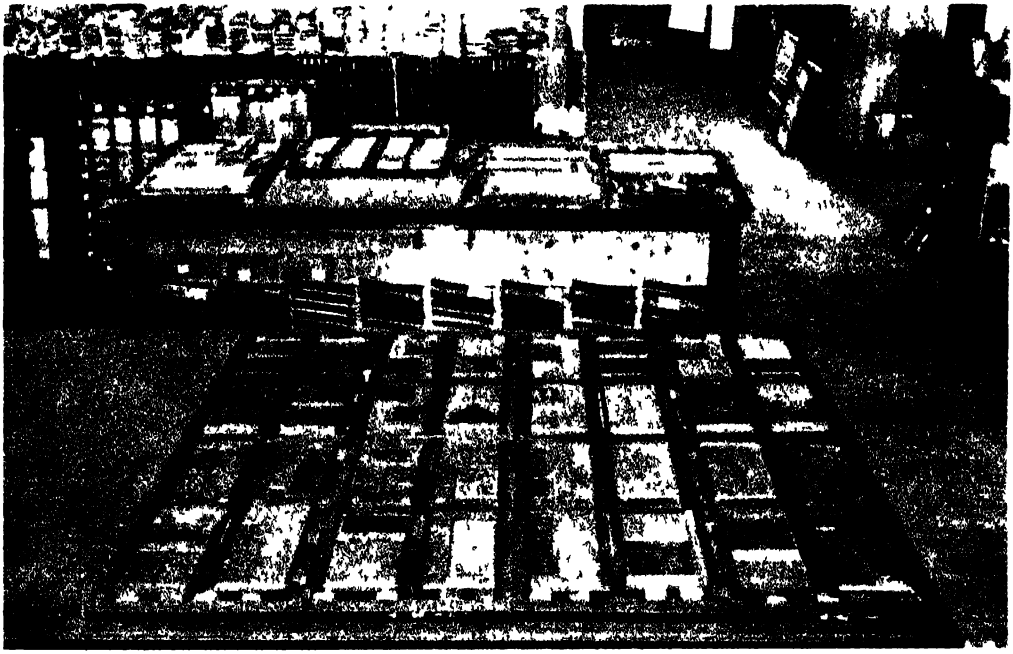
The compositor, seen in the photograph above, gathers together the type required and also the blocks which will reproduce the illustrations He has the Editor's "make-up" in front of him and with this as his guide he assembles the type and the blocks in page form and another proof is then taken



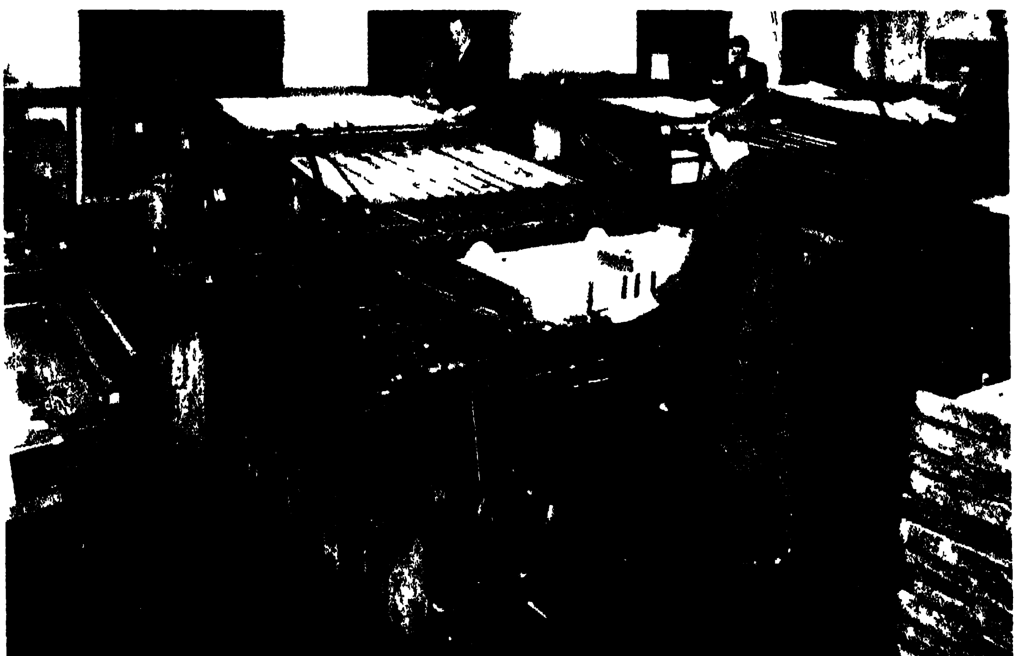
Photos By courtesy of the Whitefriars Press, Ltd

Here is the printer's proof-reader, whose duty it is to check proofs with the greatest care to see that the setting and "making-up" have been correctly done Sometimes his assistant will read aloud from the original manuscript Proof readers have a special code of signs for marking corrections

WHEN THE PAGES ARE "MADE READY"



Such corrections as the reader makes on his proof must be put right in the metal type. When the pages are ready, however, they are laid together and tightly wedged with quoins in a steel frame known as a chase. When the printed sheet is folded the pages will come together in the proper order.



Photos: By courtesy of the Whitefriars Press Ltd

This is one of the presses used for the printing of this book. The sheet of paper is fed in at the far end of the press and a revolving cylinder carries it over the inked type and pictures. Printed sheets are delivered at great speed on to the tray in the foreground.

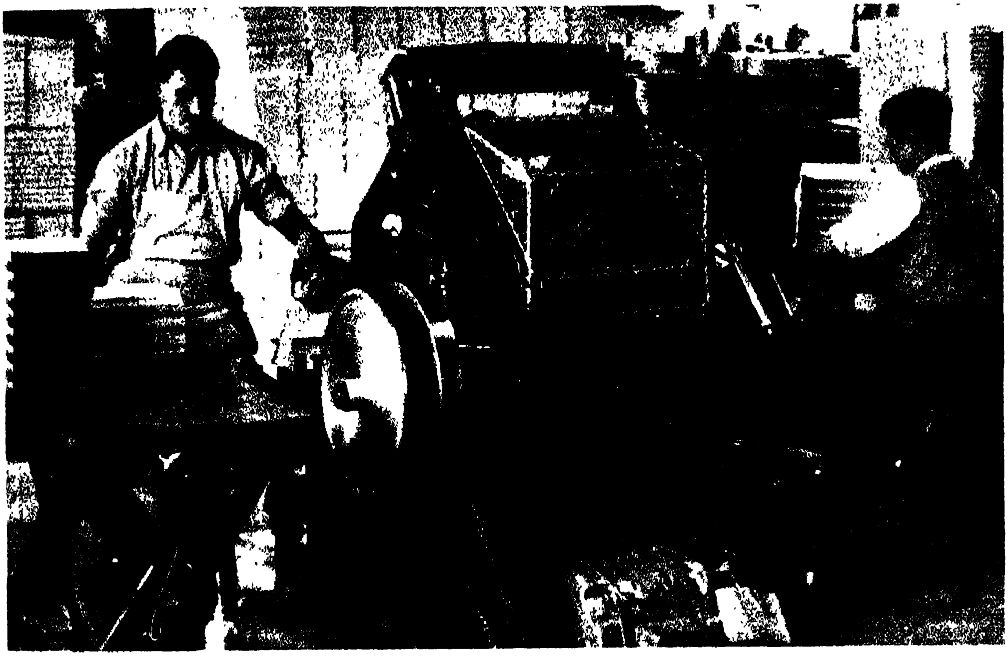
FIRST STAGES OF BINDING

Our books are printed in large sheets, each of which bears the impression of thirty-two pages of type. When the ink is thoroughly dry the sheets are folded into 16-page sections. These sections are collated in their correct sequence and are then sewn together on this sewing machine.

Photos: By courtesy of Hazell, Watson & Viney, Ltd.

We now have a complete volume with its edges untrimmed and with many of the pages still uncut. These [illegible] shown in the photograph above and here the sewn books have [illegible] evenly trimmed in one operation.

ROUNDING AND BACKING THE BOOKS

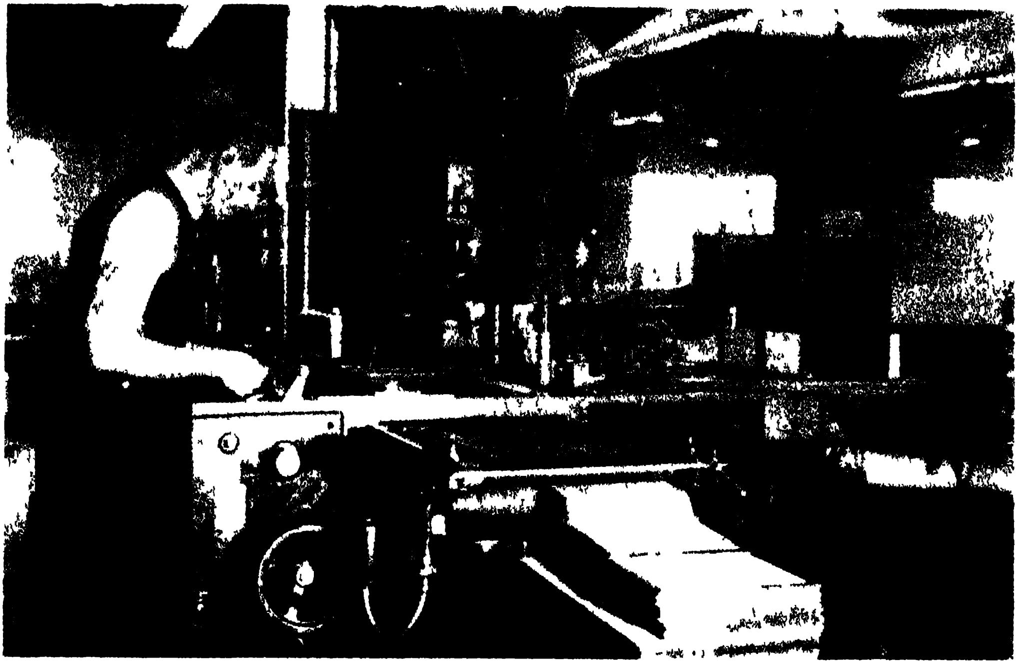


The books are beginning to take their correct shape. Before entering this machine the backs of the volumes are flat but they must now be rounded and the shoulders jointed. This is known as "rounding and backing" and provides a hinge on which the case, when pasted to the book, will open easily.

Photos: By courtesy of Hazell, Watson & Viney, Ltd.

Passing on to the next stage the books are strengthened by glueing muslin and strong brown paper linings to the backs of the volumes. In this picture we see the books being fed into the machine where these operations are carried out in their proper sequence.

THE BOOKS ARE COMPLETED



In this photograph the operator is seen at work feeding the material required for the covers into a case-making machine As it passes through the machine the material is automatically glued, fitted to the boards, and finally ejected from the machine as a cover ready for the decoration

Photos · By courtesy of Hazell, Watson & Viney, Ltd.

We come to the last stage in which the books are pasted into their covers This process is known as "casing in." When this work has been done the books are put into a powerful press where they are left to dry thoroughly They are then ready to be packed for despatch

Post Office

A TRAVELLING TELEGRAPH OFFICE

On special occasions when telegraph facilities are needed in some place where they do not exist or are too far away from the actual scene a Mobile Post Office is sent This is really a motor caravan fitted with Teleprinter and telephone which can be quickly connected up to the nearest lines and business carried on as in an ordinary Post Office

motor caravan, but fitted with teleprinter and telephone apparatus which can be quickly connected up so that no delay occurs when urgent messages have to be sent from some place where normal telegraphic facilities do not exist The adoption of teleprinter working has also enabled special events such as race meetings and big sports gatherings to be dealt with in a much more satisfactory manner than when the Morse apparatus was in use A temporary telegraph office is quickly set up and the flood of messages are dispatched without any unnecessary delay

The Pen that Destroys Distance

The word telegraph comes from two Greek words. *Tele* = far off, and *grapho* = to write. To telegraph, therefore, means literally to write something at a distance. The use of the printing apparatus about which we have just been reading is real telegraphy, if words delivered in type may be called writing; and the apparatus which we will next notice enables one to telegraph undisputedly in the full sense of the word.

What happens in this case is as follows You pick up a pencil in, say, London, and write a message with it As you do so, a pen in Liverpool, Manchester, or some other distant place copies every movement of your pencil so faithfully that what it writes is undoubtedly *your* handwriting, not that of anyone else Instead of ordinary characters you may use short-hand if you like Or, if some particular point can be explained better that way, make a simple sketch or diagram It is all the same thing to the telewriter

This service has not been developed very fully, partly owing to the fact that the ordinary telegraph and telephone provide all that is usually required, and partly owing to the war Telewriters have been in use, however, on the Liverpool Cotton Exchange, Manchester Royal Exchange, and the reporters' gallery at the House of Commons.

Wireless has played a part both in the telegraph and telephone services in the sense that experiments in one direction have opened up possibilities in another. Among the discoveries affecting telegraphy and telephony is what is termed "voice frequency" working. In the beginning each pair of persons talking over a telephone or using the telegraph instrument needed a pair of wires. Nowadays by adopting a method used in wireless each pair of wires can carry several conversations or machine-sent messages.

The sounds go over the wires as a jumble but at the other end each different voice or teleprinter message is picked out by a suitable detector and the jumble is automatically and neatly sorted out. One line between London and Birmingham actually carries 320 conversations on one pair of wires. The apparatus required at each end to combine the different conversations in the beginning and then to separate them at the end is highly ingenious, and, as can be imagined, wonderfully complicated so that no easy and simple explanation of its working is possible. Those of us who lack technical knowledge in such matters can only stand and wonder.

Cables Under the Sea

But it is this "voice frequency" system which has revolutionised the engineer's task in both telegraph and telephone practice and still improvements are being made. The introduction of this system has resulted in a complete co-ordination and harmony between the telephone and the telegraph services. The same lines serve both services and in the case of the telegraph it means that the service is nowadays almost without distance limits. On this particular system repeater stations are situated at distances of about fifty miles

There is another branch of telegraph

Post Office.

A POWER HOUSE UNDER THE SEA

One of the handicaps of submarine cables has been the fact that it was not possible to have amplifiers between the shore terminals This has now been overcome by the Post Office engineers and our photograph shows the inner assembly of the "Repeater" which forms part of the cable laid in 1946 between Lowestoft and the island of Borkum off the German coast for the Continental service This inner assembly is four feet long by 13 inches diameter and is enclosed in a larger chamber constructed of welded steel plates ⅝ inch thick which will withstand a pressure of 1,000 pounds to the square inch

TELEPRINTERS AT THE DERBY

Post Office

For special events such as important racing and sports meetings a staff of telegraphists with their Teleprinters are installed on the spot. The photograph above shows the scene on Derby Day, and although horses, jockeys and crowds are somewhere just beyond the camera's range the teleprinters are sending results and descriptions which will tell those far from the course just what has happened.

Post Office

In all branches of the Post Office service great importance is attached to the training of the staff, in the well-founded belief that a properly trained operator becomes a master of the craft and enjoys freedom from strain and so works easily. Here we see beginners at the Central Telegraph Office School learning the correct way to manipulate the Teleprinter keyboard.

Specially drawn for this work.

THE WORLD'S LARGEST CABLE SHIP AND ITS WORK

There have been four vessels which have borne the name of His Majesty's Telegraph Ship *Monarch*, the latest, an 8,058 ton vessel, is fitted with every modern device and invention for cable-laying and repairing. It was launched on the Tyne in 1945 and came into service the following year. This drawing shows some of the equipment carried and the tasks carried out by the ship. The key to the numbers shown in the drawing of the *Monarch* in the lower half of the picture is given on the opposite page

work about which a large volume could easily be written. The Post Office is responsible for 373 submarine cables, but as new cables are still being laid this figure is increasing steadily.

It was in 1850 that the first submarine cable was laid between England and France. Something went wrong very shortly after it was laid and it took a little time to discover the truth. A Boulogne fisherman had hooked up the cable with his trawl, and, puzzled by his catch, cut off a piece—and then promptly set sail for home. He believed that he had found a new and rare kind of seaweed the centre of which was filled with gold. The gold, of course, was merely copper wire and the "seaweed" had been specially made in England.

This unfortunate beginning did not deter the engineers and during the next year, 1851, the first successful cable to the Continent was laid. In 1870 the Post Office took over several cables belonging to different companies as well as the cable ship *Monarch*, a paddle-steamer of some 500 tons.

Since then there have been three other ships bearing the name His Majesty's Telegraph Ship *Monarch*. The latest *Monarch* is a large cable-laying ship of 8,000 tons, fitted with every latest improvement to enable her to make use of the many scientific developments in this important branch of telecommunication between countries separated by the oceans.

Largest in the World

The *Monarch* is indeed a wonder ship, fitted with four cable tanks in which about 2,500 miles of deep sea cable can be carried, and having electrically-operated cable gear. She was launched in 1945 and is the largest cable ship in the world.

Cable-laying is almost as highly scientific as is the work of the engineers who have devised all the apparatus now in use. Even in the deepest water the cable rests on the bottom of the ocean. When laying a cable in a depth of three miles it is calculated that, with a ship's speed of eight knots, the distance from the stern sheave where the cable leaves the ship to the point where the cable actually touches the bottom is over 20 miles. It takes a particular point in the cable more than two hours to reach the bottom from the time it enters the water.

Flashed Across the Ocean

A new cable for the Continental service was laid in 1946 between Lowestoft and the Island of Borkum off the German coast. It is 200 nautical miles long and the cable has Polythene insulation instead of the old gutta-percha covering. This particular cable is fitted with a submerged repeater which is in effect a small power house on its own, renewing the current and amplifying the messages. Like other highly technical improvements in the electrical engineers' world

H.M. TELEGRAPH SHIP "MONARCH"

Key to numbers shown in the drawing on the opposite page.

1 After Paying-out Sheave; 2. After Dynamometer; 3. After Brake Control; 4. Quarters and Corridor; 5. Refrigerated Stores; 6. Water Tanks.; 7. Starboard Propeller; 8 Starboard Propeller Shaft, 9. Feed Water Tanks, 10 Thrust Block; 11. Generating Machinery Room; 12. Engineers' Workshop, 13. After Paying-out Gear, 14 Engine Room (Starboard), 15. Boiler Room; 16. Uptakes, 17. Galley; 18. Fuel Tanks in Double Bottom, 19. Ward Room; 20. Master Gyro Compass, 21. Officers Accommodation and Corridor; 22. Starboard Motor Boat; 23. Cable Signal Lights; 24. Whip Aerials, 25. Radar Room, 26 Radar Scanner, 27. Range Finder and Compass Platform; 28. Wheel House and Bridge; 29. Chart Room, 30. Radio Room, 31. Sea Cabins and Offices, 32. Captain's Day Cabin; 33. Captain's Sleeping Cabin; 34. Sea Cabins; 35. Cabin Corridor; 36. Cable Test Room, 37. Gangway, cabins, offices, etc.; 38. Cable-Leads Testing Station; 39, 39a, 39b and 39c. Cable Stowed in Cable Tanks; 40. Crinoline Cable Guide (on each tank); 41. Cones in each Tank round which the cable is turned, 42 Pitometer Log Chamber; 43. Double Bottom; 44. Echo Sounder Chamber, 45. Fore Hold Stowage of working gear, buoys, etc., 46. Stowage Bins; 47. Hatch Trunk, 48. Forward Picking Up and paying out gear, 49. Winch, 50. Forward jockey and hauling-off gear; 51. Crows Nest; 52. Companion Way; 53. Forward Crew's Space, etc., 54. Forward Dynamometer; 55. Bow Sheave for picking up and paying out cable.

Associated Press

AS THE NEWS COMES THROUGH ON THE TAPE

This is the tape machine which is used in Stock Exchange offices, clubs, newspaper offices and other places for share quotations and news items, particularly those containing figures It works on much the same general principles as the Teleprinter.

it is impossible to give a simple explanation of its parts or its manifold purposes Yet it does help us to appreciate the marvels of our modern world if now and again we are given a glimpse of the ingenious inventions and devices which "make the wheels go round," or, in this case, flash our words in a twinkling across the wide oceans.

Another wonderful aspect which has developed within recent years is Picture Telegraphy. This differs from all other forms of telegraphy (with the exception to some extent of the Telewriter) in the fact that an exact reproduction of the original images or signs is received at the other end of the wires.

The history of picture telegraphy goes back as far as 1843 when Bain invented a system by which handwriting and simple line-drawings could be reproduced in facsimile. Then came the Belin system which was used in France between certain towns from 1924 onwards. The system now used by the British Post Office is the Siemens-Karolus

The Moving Light-Spot

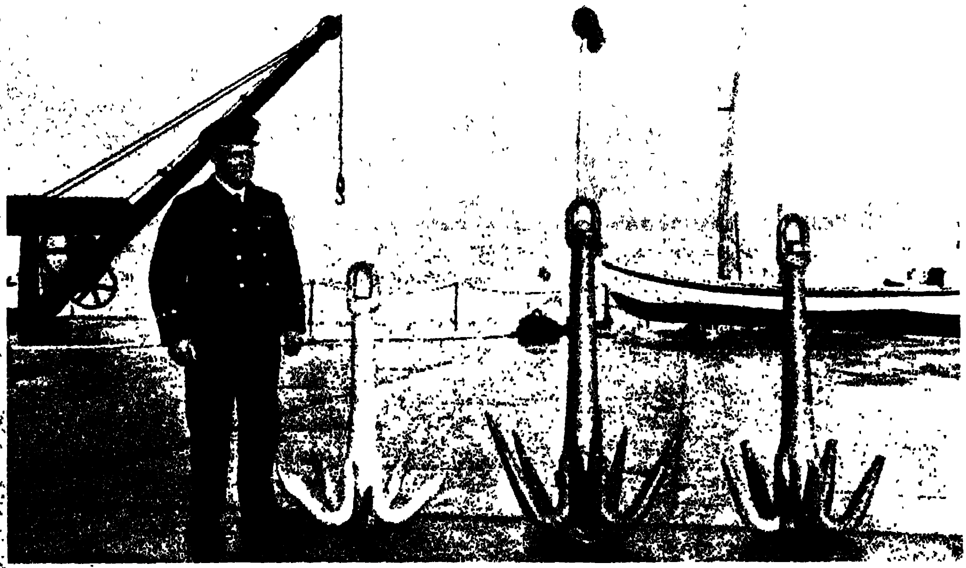
In this system the picture to be transmitted is fixed round a drum by means of spring clips. When the apparatus is started the drum rotates with uniform speed, and at the same time a spot of light is thrown on to the surface of the picture. This light-spot scans the picture with a spiral movement so that all portions of the picture from one end of the drum to the other are explored. The light from the sending lamp is interrupted by a rotating shutter in the form of a toothed disc.

The light reflected from the surface

LANDING AND GRAPPLING FOR CABLES

Sport and General

In 1926 England and America were for the first time connected by a submarine cable having its conductor wrapped from end to end in a continuous spiral of special alloy wire which greatly increases the speed of transmission and the clearness of signals. The English end of the cable is here being landed at Sennen Cove, Cornwall.



Post Office.

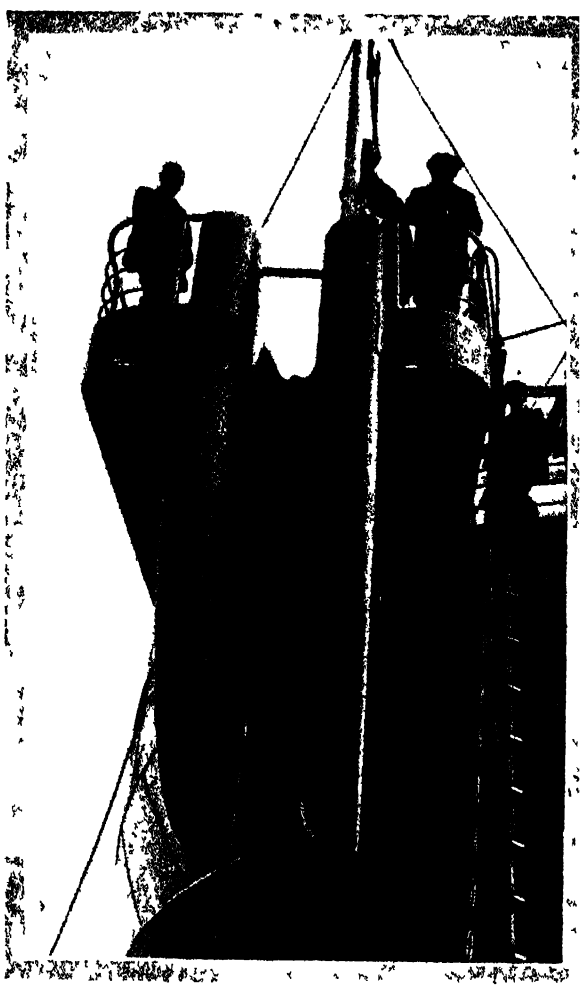
A cable ship is fitted with equipment for locating the cable lying on the ocean bed, raising it from the depths and carrying out tests to locate any faults. When the exact position of the fault is found the cable ship sails to the spot and again the cable is brought to the surface. Rafts may be used by the men carrying out the repairs. Our photograph shows some of the grapnels in use on H.M.T.S. *Monarch.*

of the picture actuates a photo-cell, and originates instantaneously a pulsating electric current proportional to the varying tones of the picture; the lighter the part of the picture the greater the current. The photo-cell current is extremely small and it is accordingly amplified in a valve amplifier, after which it is transmitted over a suitable telephone line.

At the receiving end the current is amplified in a valve amplifier and is applied to the terminals of a Kerr cell or an oscillograph. The cell controls the intensity of a light spot which scans spirally as at the sending end by being projected on to a photographic film mounted on a drum rotated at exactly the same speed as that at the sending end. The film is taken from the drum in a dark room where it is developed, fixed and printed in the usual way.

Both before and after transmission the operators at both stations speak to each other over the wire by means of telephones connected to the picture apparatus. In due course the receiving station reports whether the picture has been received satisfactorily or not.

The advantages of picture telegraphy are many, some of which we have already learned to appreciate by photographs in the daily papers, taken hundreds or even thousands of miles away on the previous afternoon. Chinese characters, shorthand, fingerprints, and even delicate lace designs have been sent by this form of telegraphy.



L.E.A.

PAYING OUT THE CABLE

Different types of sheaves are fitted on the cable ships. The bow sheaves are used for repair work or laying short cables, while the stern sheave is used when laying long cable Here, the cable is running over a special platform and sheave at the stern of a steamer.

By Wire and Wireless

At present of course it is chiefly the newspapers which make use of picture telegraphy, but it is quite likely that as time goes on and more stations are opened which cater for this kind of telegraphy there will be a big increase in its general use.

It may be, too, that a shorter and more distinctive name will be adopted in place of "picture telegraphy" as the service becomes more popular. The word "Telicon" has been suggested as

Post Office

MILES OF SUBMARINE CABLE IN STORE

The Post Office has four cable depots at Woolwich Dover Dalmuir (Clyde) and Faslane in the Gairloch where submarine cables can be stored in specially constructed tanks Each depot has about nine of these tanks and our photograph shows one at Woolwich with various types of cable in the same tank Normally these tanks are kept full of water as the insulation deteriorates if cable is kept out of water for any length of time

being in line with the well-established "telegram" and "telephone"

The Post Office controls and works all the wireless, telegraph and telephone systems in the country and a good deal of work has been done to co-ordinate these varied services The question of competition between them scarcely arises since one method is suitable for certain cases while for a different purpose another method is found best. In some cases one helps the other and a message may begin its journey across the world through the telephone, then go by cable across a wide stretch of ocean to be passed on finally by the radio operator on a wireless station to his colleague in the cabin of an ocean liner.

At different times the Post Office staff have sought an answer to the question What are the reasons which decide the choice by the ordinary sender between the telegraph and the telephone message ?

Certain types of messages must obviously be sent by telegram For example, telegrams of congratulation and good wishes in connection with weddings and other social events are scarcely suitable for telephoning Imagine the plight of bride or bridegroom at the wedding reception if a score of friends from near and afar all decided to make use of the telephone to convey their good wishes !

Then there are many business messages of which it is desirable to have a written record Here again the telegraph scores over the telephone. In the case of short-distance messages, especially where an immediate answer is desired, the telephone is generally much more convenient

Post Office

PREPARING THE PHOTOGRAPH FOR TELEGRAPHING

Photographs are now sent regularly by telegraphy. Our illustration shows a print which has been handed in to the Post Office for transmission being clipped on to the drum in readiness for sending through the wires by a pulsating electric current which gives every gradation of the different tones in the picture. This current operates a pencil of light at the receiving end and so produces a photographic negative from which prints can be made.

At one time it was apt to be assumed that, so far as its social side was concerned, the telegram was the bearer of bad news. That idea is dying out to-day. Actually less than two per cent. of telegrams come into this category, while about four per cent. carry congratulations.

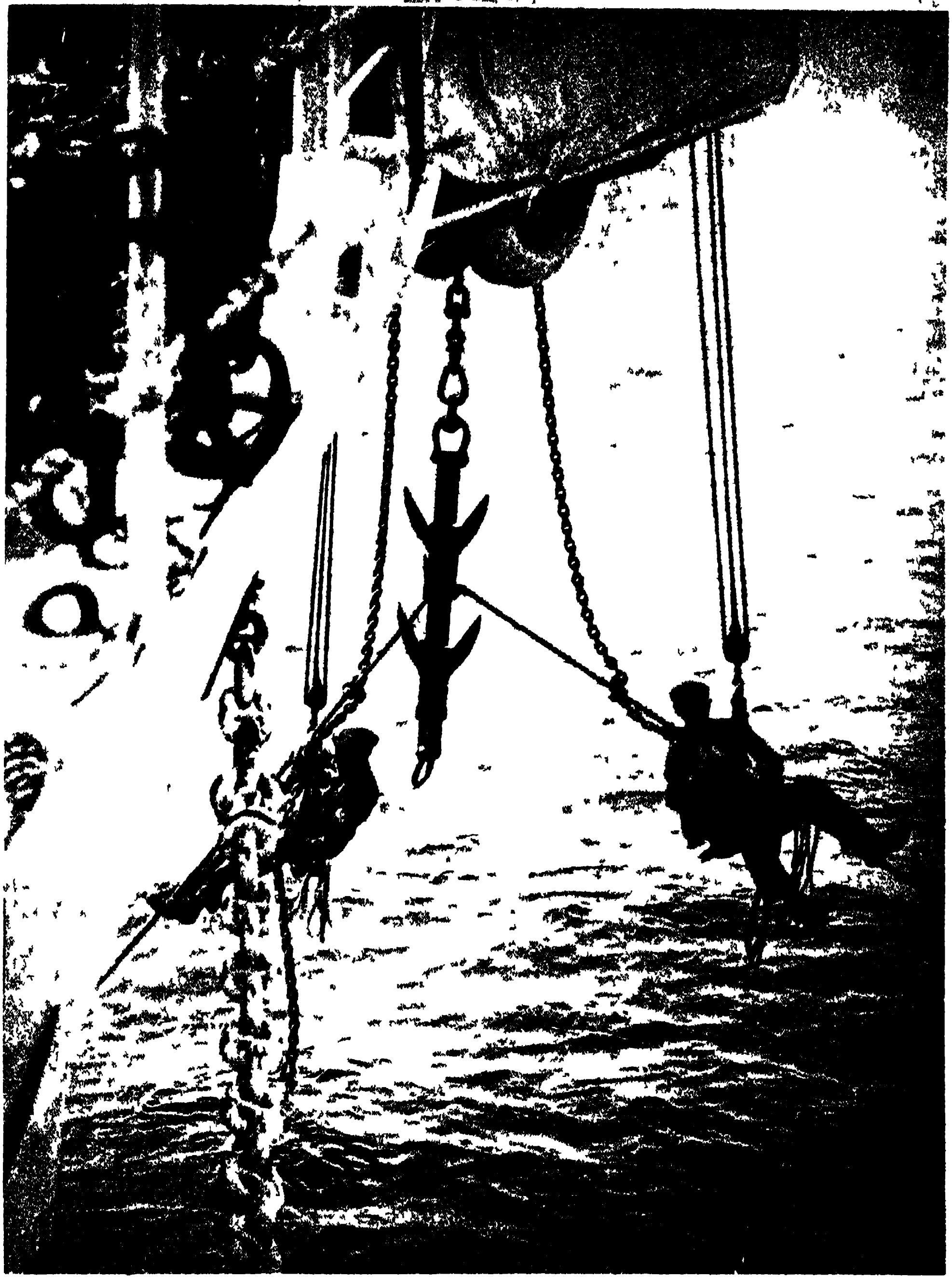
In an analysis of trade telegrams it was found that "fish" messages amounted to nearly nine per cent. of the total, and it was clear that the telegraph service plays a big part in the buying and selling of perishable goods such as meat, fruit and vegetables.

The way in which the telephone and telegram are complementary to each other is seen in the fact that nearly three-quarters of all telegrams come from the senders to the Post Office by telephone.

In this chapter we have dealt only with messages and pictures conveyed by electric current through wires. The British Post Office have of course control of the largest network of radio communications in the world. By Act of Parliament passed in 1904 the Postmaster-General became the sole licensing authority for wireless telegraphy and telephony and all wireless apparatus installed in this country or on board British ships.

It will be seen therefore that the three services, Telegraph, Telephone and Wireless, are not working in competition with each other but can be used to supplement each other. When some new invention or revolutionary method comes along in any sphere there is a tendency at first to think that the new will oust the old system.

LANDED!



G P A

After long and patient dragging this cable has been hooked and brought safely to the surface for repairs Two men, lowered on bosun's chairs have made the cable fast on both sides of the point at which it will be cut At the top of the chains we see parts of the bow sheaves of the ship

G. P. A.

A NICE LITTLE FISH-HOOK!

The grapnel, having done its work, is made fast over the bow sheaves, of which you will see, there are three. Grapnels of various forms are used to cope with different conditions of dragging

Thus the rapid advance of the telephone service in the years before the last war led many people to believe that the older telegraph system would rapidly become out of date. Radio, too, seemed likely to oust the old telegraph and cable systems when first its wonders and possibilities became apparent. The actual outcome, however, has been that radio has its own distinct field, and it is not a competitor with either the telephone or telegraph services. For inland service the telegraph has become even more important as a partner with the telephone in making swift communication.

The telephone is in the main a short-distance service while the telegram is more generally used over longer distances. Taking an average of all telegrams sent in this country the message sent via the teleprinter travels about 150 miles. The average telephone distance is very much less.

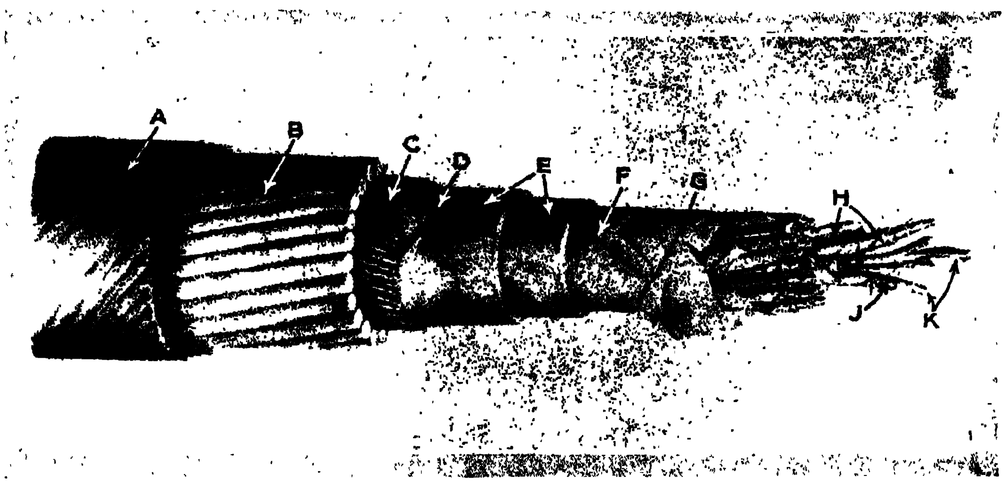
Whatever new devices and improvements may come along it is safe to say that in the next few years the telegraph services will be able to give the British public an increasing number of advantages as old systems are improved and new ideas are brought into practice.

Post Office

PICTURE TELEGRAPHY

Pictures are now telegraphed many hundreds of miles. Our illustration shows the photograph of a youngster playing on the sand which was sent as a telegram from the Continent

THE TELEPHONE AND HOW IT WORKS



Siemens Brothers Ltd.

A SUBMARINE TELEPHONE CABLE

The cable from which this sample was cut runs along the bed of the North Sea from England to Holland. It has 16 copper conductors. The letters on the illustration indicate: A and C, jute serving; B, galvanised wire armouring; D, oiled paper; E, lead sheath; F, cotton tape; G, paper wrapping; H, paper insulation; J, spiral wire, wound round K, conductor, to improve the transmission of speech.

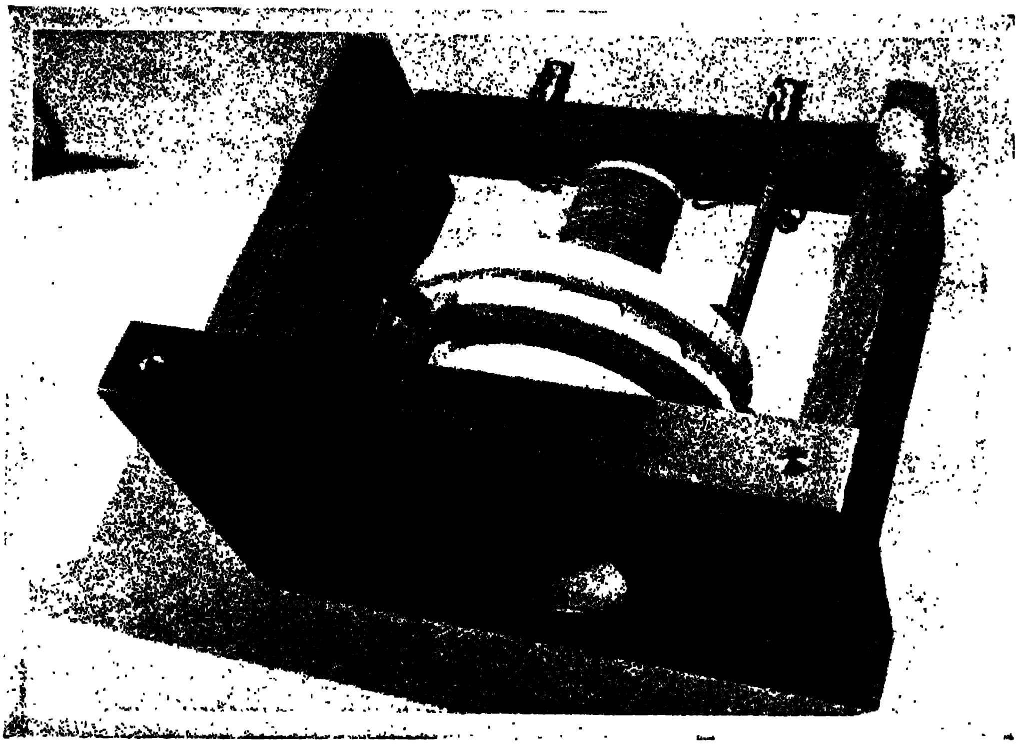
HAVING dealt with the first means of sending messages electrically—the telegraph—we will discuss the second means—the telephone. In its action, if not in its working principles, the telephone is a much more delicate apparatus than the telegraph. The telegraph transmits pulses of electricity at a rate limited to thousands a minute; the telephone transmits electrical vibrations numbering thousands a second. It is therefore able to respond to the very quick vibrations of the human voice and other sounds, and makes it possible to transmit sounds, as opposed to signals, very faithfully.

The first practical telegraph, the needle instrument, was produced in 1837. The telephone did not appear till much later. On July 1st, 1875, Mr. Charles Watson, assistant to Alexander Graham Bell, a Scottish doctor who was professor of vocal physiology at Boston University, heard words, transmitted by electricity, which were spoken by Professor Bell in another room. He could not distinguish the meaning of the words but he was sure that the sounds *were* words. After a little more experimenting the day came (March 10th, 1876) when Bell, who will always be famous as the inventor of the telephone, heard quite clearly some words uttered by his assistant, and sent back to him the first telephone message ever transmitted: "Mr. Watson, please come here; I want you." This was a memorable day in human history, for it may be regarded as the birthday of the telephone.

Bell's First Telephone

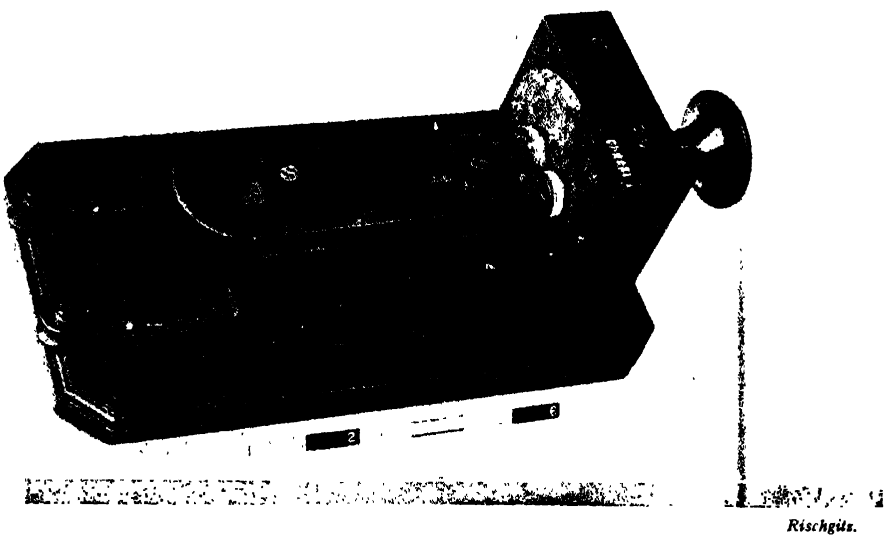
Though the instrument originally used by Bell was soon improved out of use, it deserves a short notice. At the back of its mouthpiece was a tightly stretched parchment disc, connected to a small strip of iron, one end of which was fixed and the other near the pole of an electro-magnet. The coil of wire wound on the magnet was connected at one end to earth, and at the other to a wire running to a similar instrument elsewhere with its own earth wire. When the telephone was in use it was necessary to use the same

TWO HISTORIC TELEPHONES



Post Office.

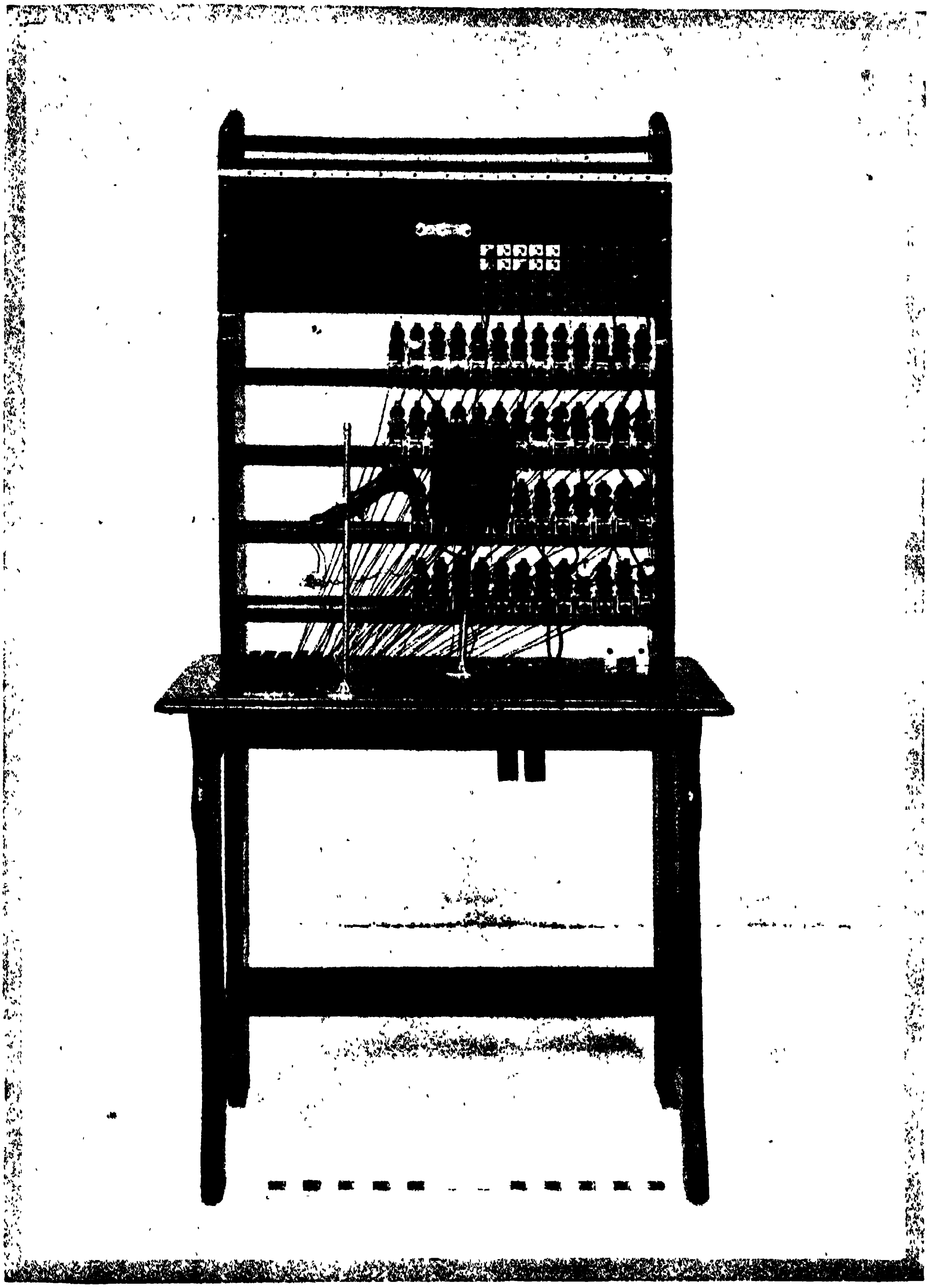
Here we have a model of the telephone, designed in 1875, which transmitted speech for the first time in 1876. It is the first ancestor of all the millions of telephones now in use and was invented by Dr. Alexander Graham Bell, an Edinburgh doctor who went to Brantford, Canada, in 1870 and later became a professor of vocal physiology at Boston University, U.S.A.



Rischgits.

Soon afterwards, Bell, the "Father of Telephony," substituted permanent magnets for the electro-magnets of his first instrument. This illustration shows his "magnetic" telephone, the principle of which is still used in all modern telephone receivers.

MORE THAN HALF A CENTURY OLD



Kischgitz.

This is a telephone switchboard such as was used in telephone exchanges sixty years ago. It looks very crude beside the wonderful switchboards of to-day. But at that time telephony was only four years old, and telephone subscribers were very few, so that it was probably large enough to meet the needs of a big town. Nowadays there are over 3,000 automatic exchanges in rural areas in this country.

transmitter for both voice and ear. The words uttered near a mouthpiece caused the parchment disc and iron strip to vibrate. The movements of the iron strip in the "field" of the magnet disturbed what are called the "lines of force" of the magnet, and produced variations in the current flowing through the coil and line corresponding in frequency to the vibrations of the voice. These current variations altered the pulling power of the magnet in the instrument at the other end of the line, so that it moved its iron strip and the parchment attached thereto in exact time with the movements of the other parchment. Waves set up in the air by the disc of the receiving instrument reproduced the words spoken into the transmitter.

Bell soon improved his first instrument by using permanent magnets in place of electro-magnets in his apparatus. The new device served, like its predecessor, for both sending and receiving. Its construction was practically the same as that of any modern receiver—the thing which you lift off the instrument and hold to your ear when you ring up or answer the exchange. If we took this to pieces we should find an iron disc at the back of the mouthpiece, very close to one pole of a long bar permanent magnet. Round the disc end of the magnet is wound a coil of wire, the two ends of which are connected to the wires in a flexible cord entering the back end of the instrument.

Bell's second telephone outfit consisted, then, of two of these instruments connected by two wires. When one was spoken into, the vibrations of its

Post Office.

THE INTERNATIONAL TELEPHONE EXCHANGE

Telephonic communication with practically every country in the world can be made from Britain, and all such communications pass through the International Telephone Exchange at Faraday House, London. Here we have a view of the operators at work on one section of the big switchboards, and the names of a few of the very many distant places with which telephonic connection is made can be seen above the boards.

Post Office.

THE HAND MICROPHONE AND ITS PARTS

Our illustration shows the hand-microphone telephone instrument now in general use throughout the country. In the diagram on the top right-hand side are shown (1) the transmitter contacts, with (2) the mouthpiece into which one speaks; (3) the transmitter, (4) the receiver electro-magnets, (5) the receiver diaphragm, and (6) the receiver cap, or ear cap, which brings the voice of the speaker at the other end to the listener's ear. The position of these different parts is shown in the drawing on the left-hand side. In some instruments the bell is contained in the base or it can be a separate attachment on the wall.

iron diaphragm altered the lines of force of the magnet and caused tiny currents to be " induced " in the coil round it. These currents, passing through the line, affected the magnet in the other instrument, alternately strengthening and weakening its pull on the iron disc near it. So this disc vibrated in time with that at the transmitting end, and reproduced the sounds. In order to carry on a conversation it was only necessary to provide two instruments at each end of the line, connected together and to the line wires.

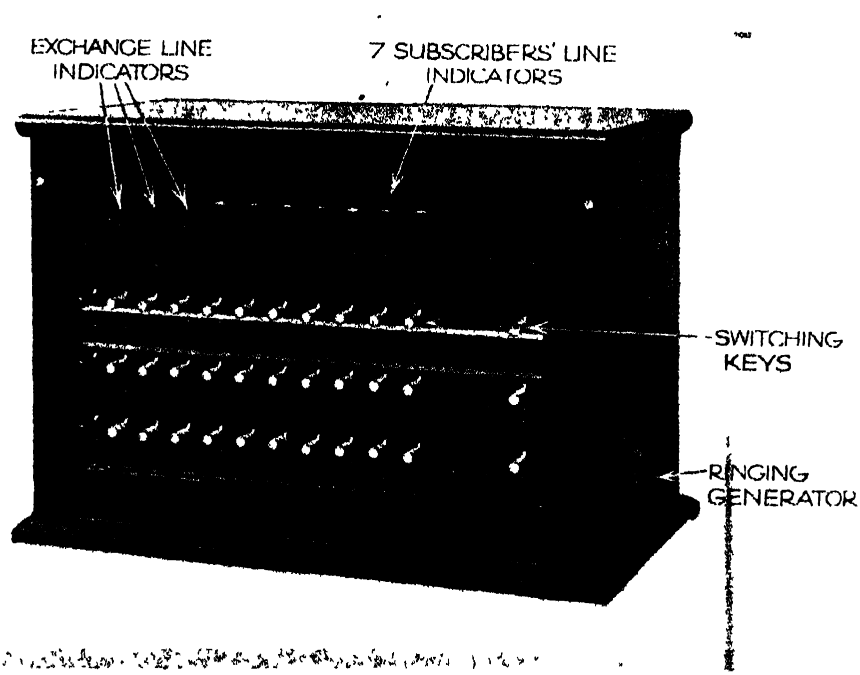
Modern Telephones

While the Bell permanent-magnet instrument has been retained for receiving, great improvements have been made in transmitting apparatus. At the back of the mouthpiece into which one speaks is a device called a microphone. This consists of carbon grains packed between two carbon plates,

which are connected with the poles of a battery. The current flows from one pole to the other through the grains. The vibrations of the voice shake one of the plates and vary the pressure between the grains, which pass current more freely when pressed more tightly together. The receivers at each end of the line may have no direct connection with the transmitters. Currents produced in a transmitter are imparted to the circuit containing the line wires and receivers through a thing called a transformer or induction coil. This has two separate windings of insulated wire round a single iron core. One winding forms part of the microphone circuit, the other is part of the line wires and receivers circuit. So when either transmitter is spoken into and currents pass through its coil in the transformer, currents are induced, or formed by sympathy, in the line wires and the receivers at both ends of the line. The transformer windings are so arranged that the induced currents are at a higher pressure than the microphone currents, and therefore able to travel more easily through the line.

Every telephone instrument is provided with a bell, which attracts attention to it when a distant person wishes to speak; and with a switch which puts the bell "in circuit" with the line when the receiver is hung on its hook.

So extraordinarily sensitive is the telephone that a movement of a transmitter disc at one station through a 10-millionth part of an inch will cause a corresponding vibration in the receiver of another station! This great sensitiveness of the receiver is such that it is necessary to use *two* line wires in a telephone circuit, one taking the place of the earth "return" in telegraphy, to



Post Office

A SMALL TELEPHONE EXCHANGE

In many offices a private telephone exchange is installed and our photograph shows a small telephone switchboard with three lines from the main exchange by which outside subscribers can be connected with any of the different departments in the office. The operator uses an ordinary telephone instrument which will have a dial if the main exchange is automatic.

Post Office

WHERE THOUSANDS OF LINES MEET

In this photograph we have a view of the main trunk lines switchboard at Faraday House, the Telephone Services Headquarters in London. It will be noted that this is a manual exchange as the automatic system is unsuited for trunk calls. Some idea of the thousands of connections made from different exchanges and subscribers in London or in other areas which can be best linked with some distant town through London can be gathered from the long line of operators all kept fully employed during the busy hours of the day.

avoid interference from stray earth currents.

Apart from human speech, the telephone is applied in many ways to the picking up of faint sounds or electrical vibrations. One important use is the reception of wireless signals.

Telephone Exchanges

The usefulness of the telephone depends largely on the possibility of users being able to get quickly into communication with each other. The wires of every telephone in a district run to a switchboard in a building called a telephone exchange, where any pair can be connected in a moment with any other pair ending there, or, through connecting lines, with any pair ending in another exchange.

The connection is usually made by hand. But very many exchanges are automatic, and a subscriber, by working a dial at his instrument, can call up any other subscriber.

The automatic exchange, as it is called, may be compared to a motor car. It has no mind of its own, but will respond exactly to proper guidance. It rings up any number wanted, signals if the number is engaged, cuts off subscribers at the end of a talk, and records the call. Seldom, if ever, does it make a mistake.

The mechanism of an automatic exchange is so very complicated that it can only be explained in technical terms. Just to give you some idea of its complexity, we will tell you this: In an exchange with 9,999 subscribers

the switching is able to make any one of 2,400,000,000 different connections.

By Night and Day

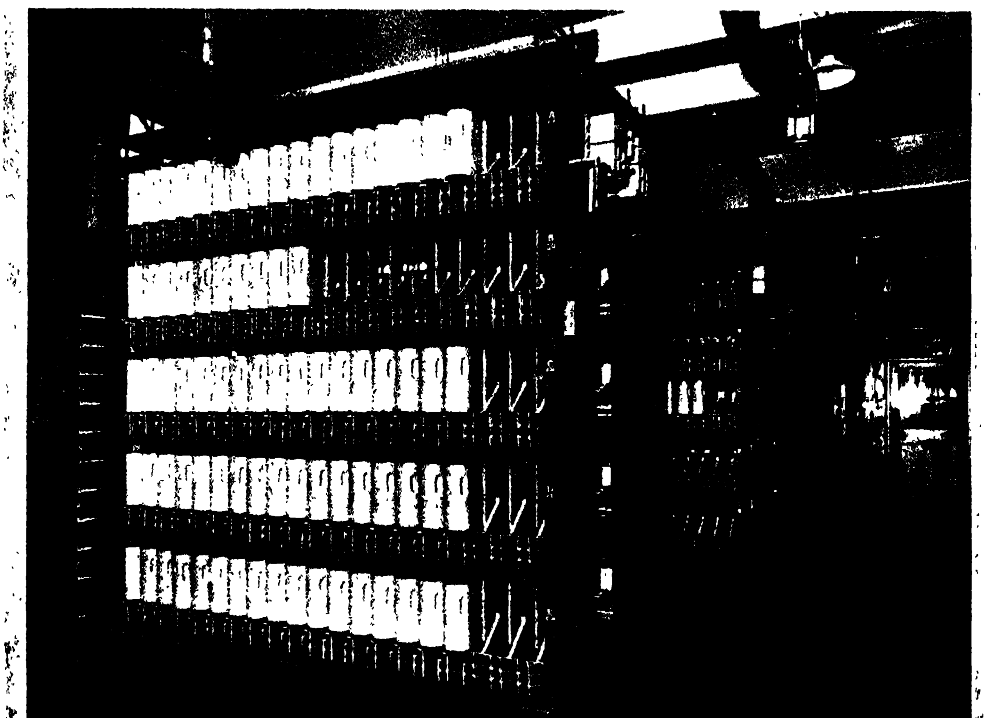
But we can at least explain something about automatic telephone working. The automatic exchange is rapidly ousting the manual exchange, and for several good reasons. It gives quicker service, and as good service by night as by day ; and it is quite secret.

In the London area we can say that it has been almost completely adopted. And a sign of this is that in the London Telephone Directory, and in many provincial directories, the first three letters of every exchange are printed in heavy capital letters : GERrard, HOLborn, VICtoria, CHAncery, WIMbledon, and so on. In using a dial instrument one has merely to dial the first three letters of the Exchange required, followed by the number.

Let us have a look at a telephone instrument used by a subscriber connected with an automatic exchange. At the base of it is a dial with ten holes in its face near the edge. Behind the holes we see the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, in this order. We see also letters of the alphabet, except behind hole No. 1, in this fashion :

ABC	DEF	GHI, and so on
2	3	4

Suppose that a subscriber wishes to ring up someone on the—well, let us call it the HAMbledon—exchange. He lifts off his receiver, puts a finger in the H hole, and turns the dial clockwise till



General Electric Co., Ltd.

IN AN AUTOMATIC EXCHANGE

This is some of the very wonderful apparatus which connects subscribers in an automatic telephone exchange. When a subscriber "rings up" the exchange, one of the many "selectors" seen in the racks will at once begin hunting for the number for which he has asked by working the dial on his instrument.

WHERE MACHINERY REPLACES FINGERS

General Electric Co Ltd

In another part of an automatic exchange will be found the extraordinarily ingenious devices called "directors," which enable a subscriber to put through a call to any exchange in his area. Even if his call has to pass through two or three intermediate exchanges to reach the subscriber wanted, the directors clear the path for him in obedience to the three "code" exchange letters which he dials before giving the number

his finger comes up against a stop. Then he withdraws his finger and the dial turns back into its original position. The letters " A " and " M " are dialled in the same way. Immediately the dial has returned into place for the third time he is " through " to the Hambledon exchange.

He may have to go through two, or even three, exchanges to get Hambledon. It doesn't matter, the code will perform the task thoroughly, for things are so arranged that no two exchanges have the same first three letters in the same order or of the same value. Our subscriber then dials the number wanted immediately after dialling the letters of the exchange.

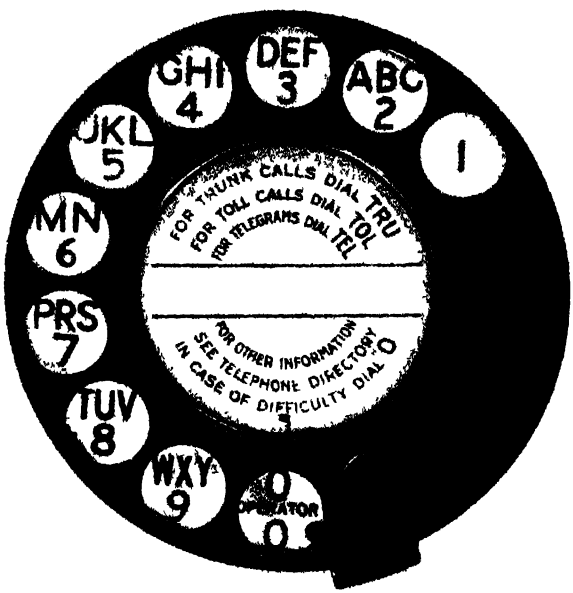
As in telegraphy, experiments are continually being made to improve and extend the uses of the telephone. Not only the Post Office technical staff but the communications engineers on our railways are carrying out development work which will combine the ordinary telephone system of the country with radio telephony.

It is possible that in the near future a business man travelling from London to Newcastle by train will be able to ring up his office in the City and talk over the telephone with a member of the staff just as easily as he could make the call from a town office.

Another application of this system is designed to equip all railway breakdown trains with apparatus which will enable them to communicate with headquarters through the nearest signal box, the operator in the box switching the conversations on to the normal railway telephone system.

The invention of the telephone was due to what might be called the hobby of a medical man who specialised in vocal physiology and was interested in sound and phonetics. He experimented in transmitting sound by electricity and by light. The outcome was the first telephone instrument seen on page 190.

Graham Bell lived until 1922, long enough to see the telephone become an essential part of business and family communication throughout the world. The centenary of his birth was celebrated in 1947 by engineers in many countries, and there are many thousands of people to-day who owe a debt of gratitude to the Scottish-American doctor whose pioneer efforts produced the first telephone.

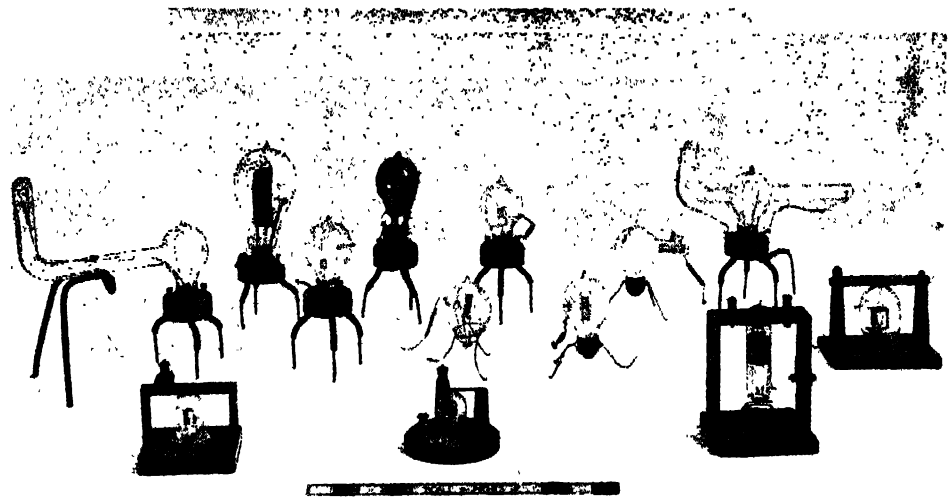


General Electric Co., Ltd.

THE CALLING DIAL OF AN AUTOMATIC TELEPHONE

To signal any letter or figure, the subscriber places the tip of a finger into the hole through which it shows, and revolves the dial in the direction taken by a clock's hands, until his finger strikes the stop at the bottom. As the dial flies back after being released the signal is sent.

THE MARVEL OF RADIO



Ellison Hawks

VALVES USED BY EARLY EXPERIMENTERS

The invention of valves for wireless came about in 1904, marking one of the greatest advances in the reception of sounds and signals through space. A valve is not only a receiver, but also an amplifier. We see in the above print some types of early valves. Wireless telegraphy is now a little more than forty years old, and wireless telephony was invented more recently.

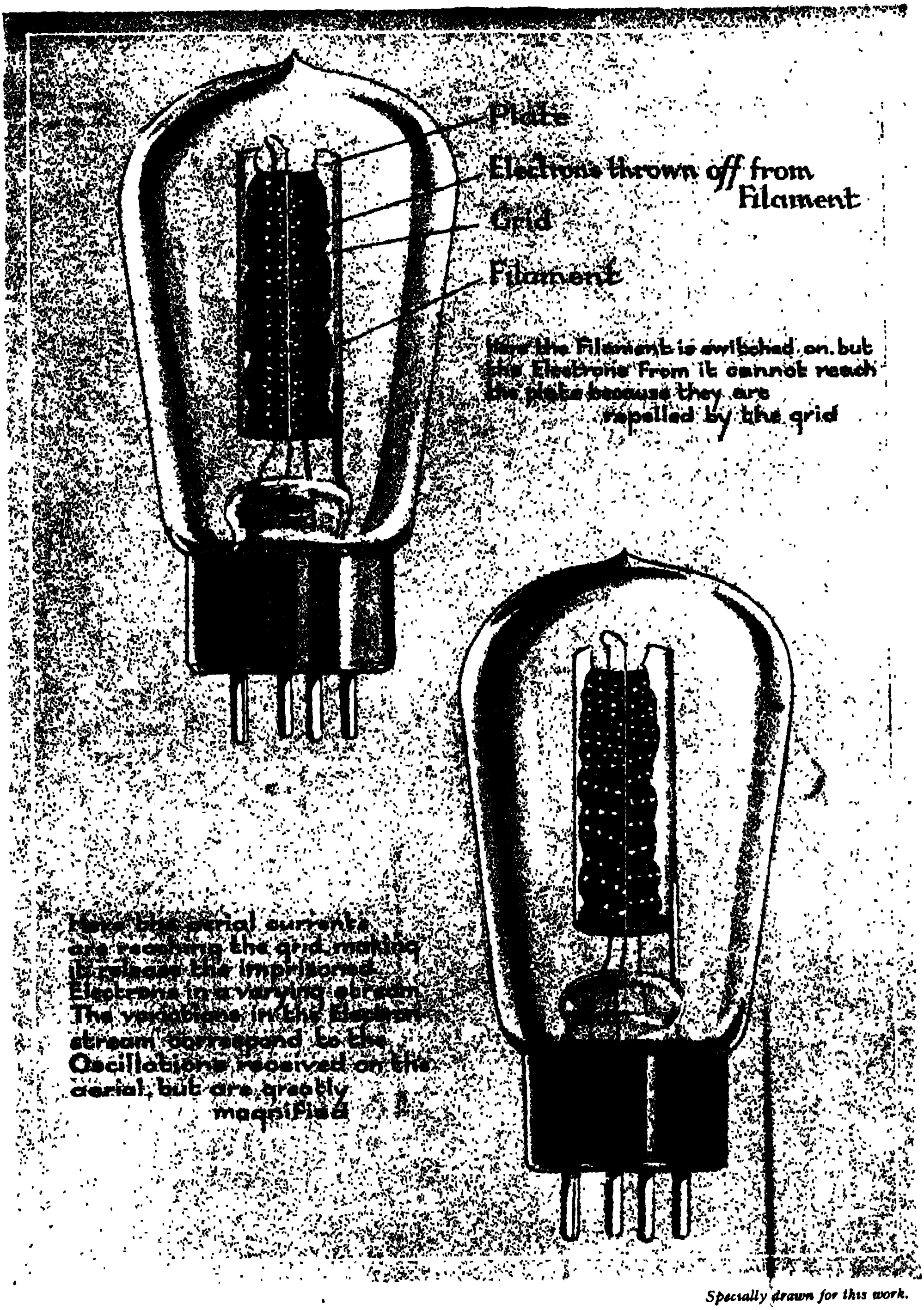
TURNING on the radio to-day is just as easy as turning on a tap to obtain water, but it is much more exciting. A water tap will give hot water if it is a hot water tap, or cold water if it is a cold water tap. But we all know that by turning the right switch on a modern radio set, we can listen to any of a dozen or more different programmes.

There is a great romance behind this. It all began in this country in the year 1867. In that year a great British scientist named James Clerk-Maxwell suggested that it might be possible to create waves of electricity which would travel through space at the same speed as light. These waves were not discovered until 1887, when Heinrich Hertz, a German professor of physics, made his famous discoveries, on which "wireless," as we familiarly call it, is based.

Passing Through Space

Hertz used an induction coil to make sparks jump across the space between two brass balls, just as the magneto of a motor car makes sparks jump gaps in the cylinder sparking plugs. He found that, if an almost complete ring of wire were held near the apparatus, sparks appeared in the gap between its ends. Waves of some kind had passed through space from the one thing to the other, setting up currents in the second.

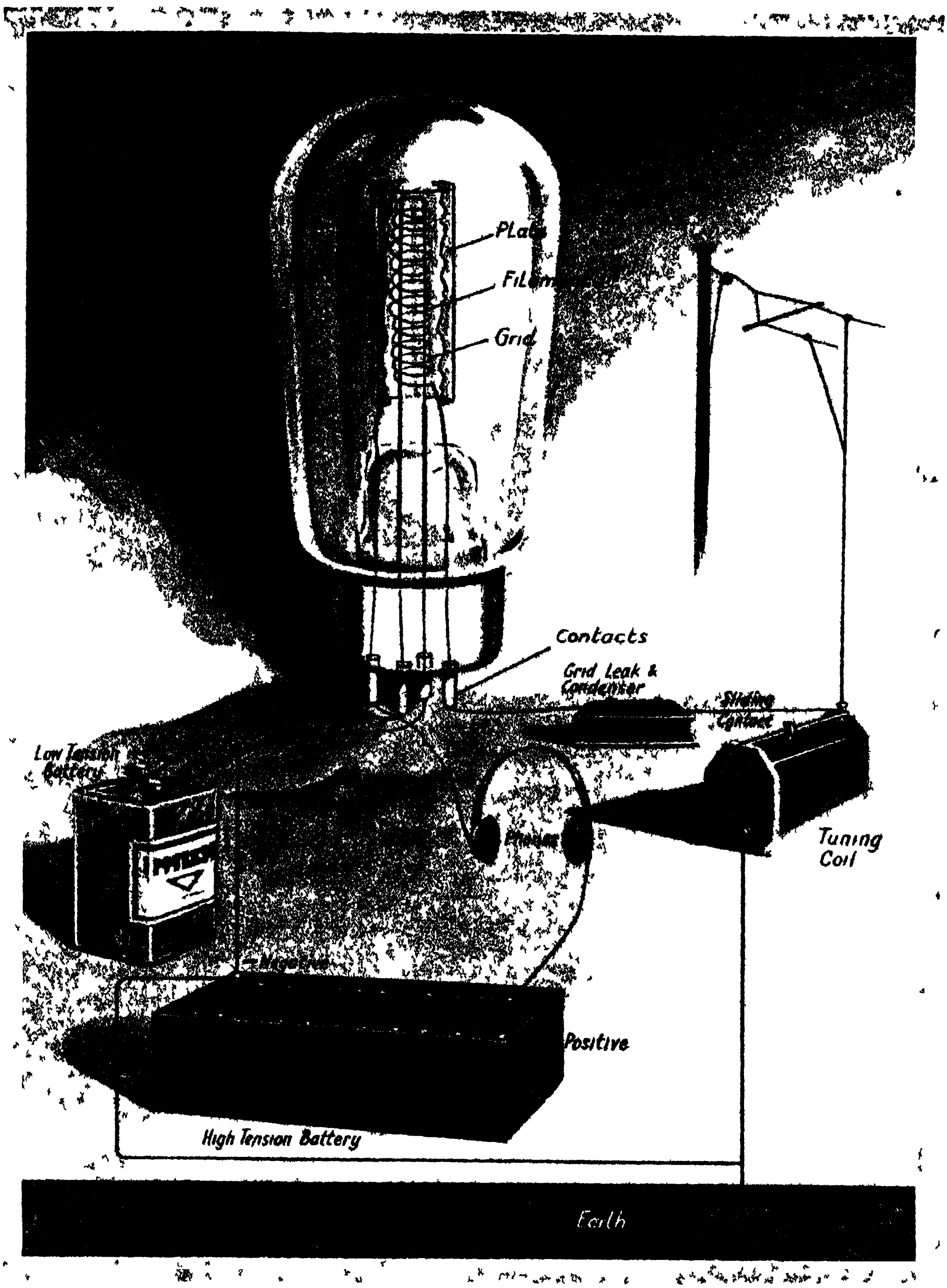
Once scientists had discovered that electrical waves could be passed through space they began to experiment on finding better and better means of generating these waves at the transmitting end and better and better means of picking up the waves at the receiving end. One of the most important further discoveries was made by Sir Oliver Lodge, a Birmingham scientist. In 1897, Sir Oliver, who was then Mr. Lodge, found that if the sending circuits and receiving circuits were tuned with each other the reception of wireless signals was very greatly improved.



Specially drawn for this work.

At first sight a wireless valve might be mistaken for an electric lighting bulb, but the resemblance is really only superficial. The device is called a valve because it allows current to pass through it in one direction only. The electrons forming the current jump from the glowing filament to a small plate, on their way traversing the coils of a "grid," which varies their flow.

HOW CURRENT GOES THROUGH VALVES



Specially drawn for this work

This pictorial diagram explains how a valve catches electrical pulses coming through the ether and makes use of them The tiny currents set up by wireless waves in the aerial reach the regulating grid of the valve through a grid leak and condenser The low-tension battery is connected with the filament of the lamp to make it glow and supply electrons which are sucked in gusts through the plate and headphones by the pull of the high tension battery

What is meant by tuning ?

The easiest way to understand what is meant by "tuning" a radio receiver is to think first of all of an ordinary tuning fork pitched, or tuned, to a particular note, say, the middle C. If this tuning fork is set in vibration and another tuning fork of a different pitch is brought near it, the second fork will not respond very much to the vibrations of the first tuning fork, because its natural period of vibration is different. If we now bring a third tuning fork which is tuned to exactly the same note as the first one and placed at some distance away from the vibrating fork it will immediately respond to the C note, because the sound pulses from the first tuning fork reach it at just the right intervals.

In other words, if we wish to make any tuning fork give out its note, this is easily done by striking it against some hard object, but if we wish to keep the fork sounding continuously we must supply it with a series of very rapid impulses which correspond to the frequency or note to which it is tuned. In the example mentioned above, the first tuning fork was sending out sound waves at just the right frequency to start the similarly tuned fork vibrating in sympathy.

Now, it so happens that the electrical circuits used in radio transmitters and receivers behave rather like tuning forks, but instead of the vibrations being mechanical vibrations which we hear as a musical note these circuits vibrate or oscillate electrically. These circuits have another convenient property, namely, that by the turning of a condenser knob they can be tuned to respond to different electrical notes or frequencies.

Sir Oliver Lodge discovered that if the receiving circuit is tuned to the same frequency as the transmitting circuit the radiations or waves sent out from a transmitter would be picked up by the

B.B.C.

PROGRAMMES FOR OTHER LANDS

One branch of the B.B.C., known as the Transcription Service, records special programmes on light weight discs and these are supplied to broadcasting organisations all over the world, particularly countries of the Commonwealth. In the photograph above a recording is being made of the programme which is being played in the studio on the other side of the window.

receiver through its aerial very much more easily than would be the case if the circuits were not tuned.

To-day when we tune our radio receiver to any particular broadcasting station we are making use of this important discovery.

One of the first men to apply these discoveries on a commercial scale was an Italian, Guglielmo Marconi.

B.B.C

ON THE LIGHT PROGRAMME

In this photograph the Continuity Engineer is at the control position, selecting the various programme items, time signals, etc., in their proper turn. The programme is "faded up" and adjusted to the proper volume, while the exact times of all programmes, with technical details, are entered in the log book.

Across the Atlantic

In December, 1901, wireless signals were sent across the Atlantic for the first time, and really long-distance wireless telegraphy began. The current needed to emit signals was now supplied by electric generators giving out hundreds of horse-power. For receiving signals the crystal detector, which was later used in the first domestic wireless sets, came into use, for it was discovered in 1906 that if the currents from the aerial were made to pass through a crystal touching a piece of metal—or through two crystals pressing on each other—and a telephone head-piece, the signals could be heard even if too weak for other kinds of detectors to pick them up.

At that time all radio signalling was done by the dots and dashes of the well-known Morse code invented by an American, Mr. S. F. B. Morse. The next important step forward was the discovery of the radio valve. Professor J. A. Fleming, who later became Sir Ambrose Fleming, took the first step towards this discovery. He made a very simple form of valve known as the Fleming Valve. This was improved by an American, Mr. Lee de Forrest. In its improved form the valve enabled speech and music to be broadcast and received at great distances with surprising clearness.

This rapid progress in the technical development of Radio was accompanied by a very great public interest. Experiments by private individuals and large manufacturers had shown that it was now quite possible for every one to have an inexpensive home radio receiver, which could be tuned to pick up radio programmes from a large number of different stations. Six

"HERE IS THE NEWS" *BBC*

Most important of all regular items broadcast by the B B C are the news bulletins Our photograph shows one of the best known of the team of news readers and announcers, Frank Phillips about to read the news in the Home Service

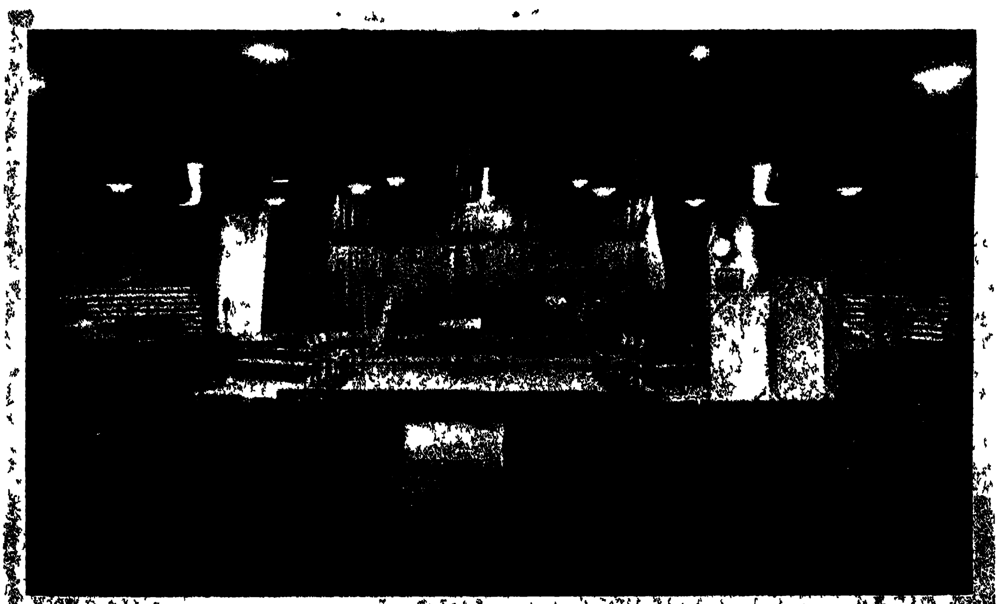
of the largest electrical manufacturers combined together to form the British Broadcasting Company. These manufacturers were: The Marconi Co., The General Electric Co. Ltd., The British Thomson - Houston Co. Ltd., The Metropolitan Vickers Co. Ltd., Siemens, Ediswan Co.

For a period of two years the B.B. Coy. transmitted broadcast programmes which were available to any one possessing a radio receiver. At the end of this period the Company was taken over by the Government and became The British Broadcasting Corporation. This occurred in the year 1925, and the Corporation still functions as a national concern under a charter from the Government.

How Radio is Broadcast

What happens when you tune in the radio to a particular broadcasting station?

In order to answer this question let us pay a visit to Broadcasting House and enter the studio from where the



ALL READY FOR THE CONCERT BROADCAST *BBC*

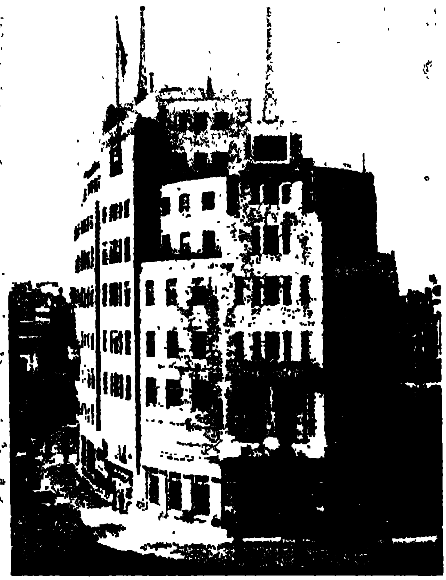
In this photograph we have a cinema which has been specially arranged as a concert hall for a B B C. broadcast The task of making the necessary arrangements for broadcasts from halls outside the studios at Broadcasting House is all in the day's work of the B B C engineers and other experts

next item on the Home Service programme is being broadcast.

We should find that the studio is like a moderately sized concert hall with platform for the artists, orchestra and audience. The walls of the studio are covered with curtains to prevent echoes. At one end of the room will be seen a large clock face with the seconds hand revolving steadily, so that the programme announcer is able to begin and finish to the second.

Whilst the audience have been entering the studio the microphone has been disconnected from the broadcasting system. As the time approaches for the broadcast to begin the doors of the studio are closed and a red light flashes on to tell the announcer that the microphone is now "live," so that any sound which reaches it will be broadcast to the listening millions.

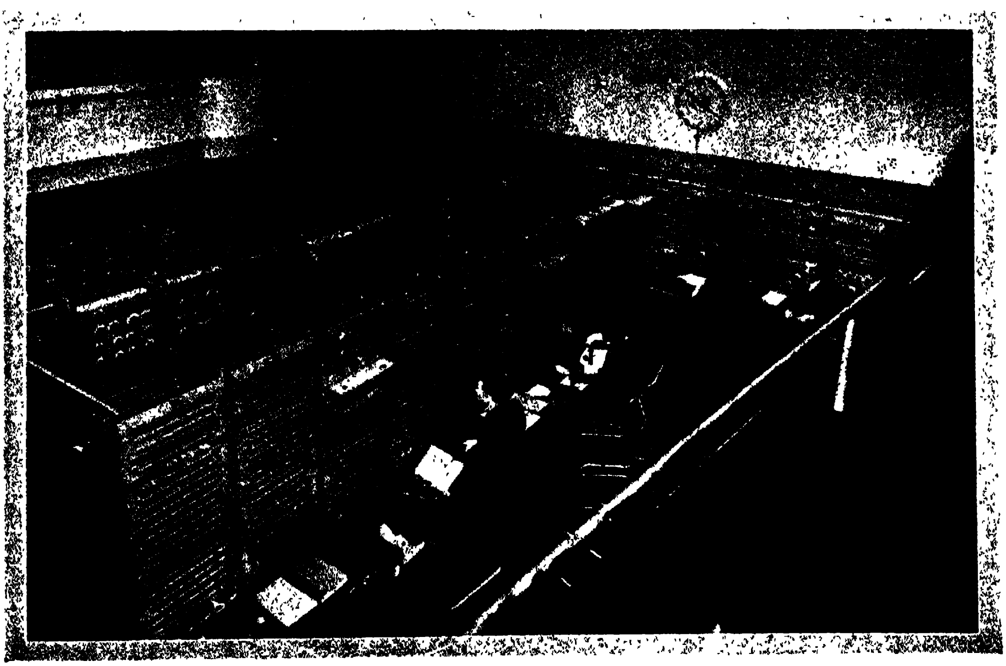
After the opening announcement the artists come up to the microphone and go through their performance, the orchestra strikes up at the appropriate



B.B.C.

THE HOME OF BROADCASTING

Broadcasting House, Portland Place, London, W.1, is the main headquarters of the B.B.C. There are regional headquarters in the provinces.

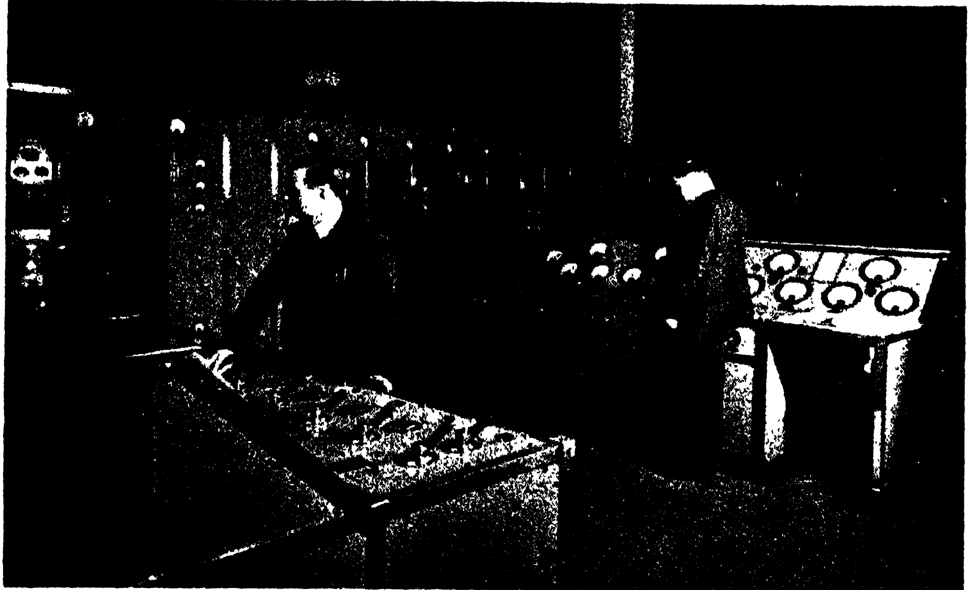


B.B.C.

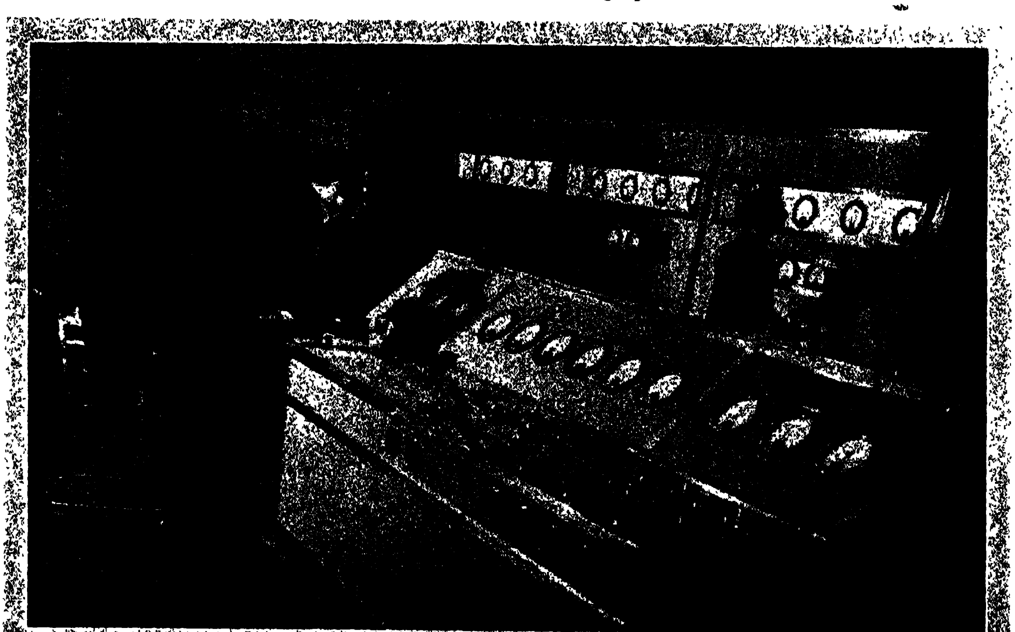
IN THE CONTROL ROOM

The task of the engineers is of paramount importance, and in this photograph we see some of the operators on duty in the Control Room at the B.B.C. headquarters.

AT THE B.B.C. TRANSMITTING STATIONS



Sounds made in the studios, whether by the human voice or musical instruments, are first caught by the microphone, but before these sounds can reach your set they have to be sent into the air and given the power to travel through space. This work is known as transmitting, and here we see the control desk of a high-power transmitter.



B.B.C.

The upper photograph is of a short-wave transmitting station, while the one below is a medium-wave transmitter. These stations are at Brookman's Park, North London, from where many of the B.B.C. programmes are transmitted on different wave-lengths so that the listener in his home can tune in his set to receive the particular programme desired.

"CALLING ALL CARS!"

Marconi's Wireless Telegraph Co

Scotland Yard and other police headquarters make considerable use of radio in these days when the law breaker also has at his disposal scientific devices and rapid transport. Here we see an up-to-date police car fitted with Marconi wireless equipment for communicating with Headquarters or with other police cars

Marconi's Wireless Telegraph Co

All sorts and all sizes of wireless receivers can be obtained these days but a wireless transmitter presents more difficult problems. Here we see a Marconi portable field equipment for communication on short-wave (transmitter, receiver and pedal generator) in actual use

moments and the sound-effects man approaches the microphone from time to time with his special apparatus to produce the various sounds which may be required to convey the right atmosphere of the broadcast, the opening and closing of a door, the dropping of crockery, the withdrawal of corks from bottles, the sound of waves breaking on the seashore. In fact, almost any desired sound can be supplied to order.

"Put on the Air"

The artists' scripts are typed on special paper which does not rustle when the sheets are turned over, because any rustling would be heard on a magnified scale by millions of listeners.

The audience in the studio may consist, of, perhaps, 200 people listening with all ears. There is in addition, one artificial ear which listens for the millions of people who have just tuned in their sets to hear the broadcast from this particular studio. This artificial ear is what we all know so well as the microphone. The jokes, the music, the sounds of opening and closing doors and the other sounds incidental to a broadcast cause a tiny coil in the microphone to vibrate or tremble in perfect sympathy with each and every sound. This tiny coil is finely poised between the poles of a powerful magnet.

Many years ago it was discovered that if a coil of wire was moved to and fro between the poles of the magnet, small electric currents were generated in the coil, the strength of these currents depending upon the amount of the to-and-fro movement. This is exactly what happens to the microphone coil whilst the broadcast is going on. The tiny currents which are set up in the coil, corresponding to the various sounds reaching the microphone, pass through an electric cable into the control room of the transmitter. From the transmitter wireless waves are being radiated from the aerial. These waves are tuned to a certain wavelength, *i.e.*, for the Home Service programme 342·1 metres.

By an ingenious arrangement of valves, the microphone sound current is first made much greater or amplified and then fed on to the control grid of the large transmitter valve. The sounds from the studio are in this way radiated into space from the aerial, or "put on the air," riding on the back of the main carrier wave which is being transmitted.

When you tune your set to the Home Service wavelength of 342·1 metres your set becomes responsive to this particular carrier wave which, as we have already seen, is now carrying on its back the sound current as produced in the studio microphone. The circuits and valves inside your receiving set reverse the process which has taken place in the transmitting station. They separate from the main carrier wave the sound current which was originally superimposed on it, and they deliver this sound current to the speech coil of your loudspeaker.

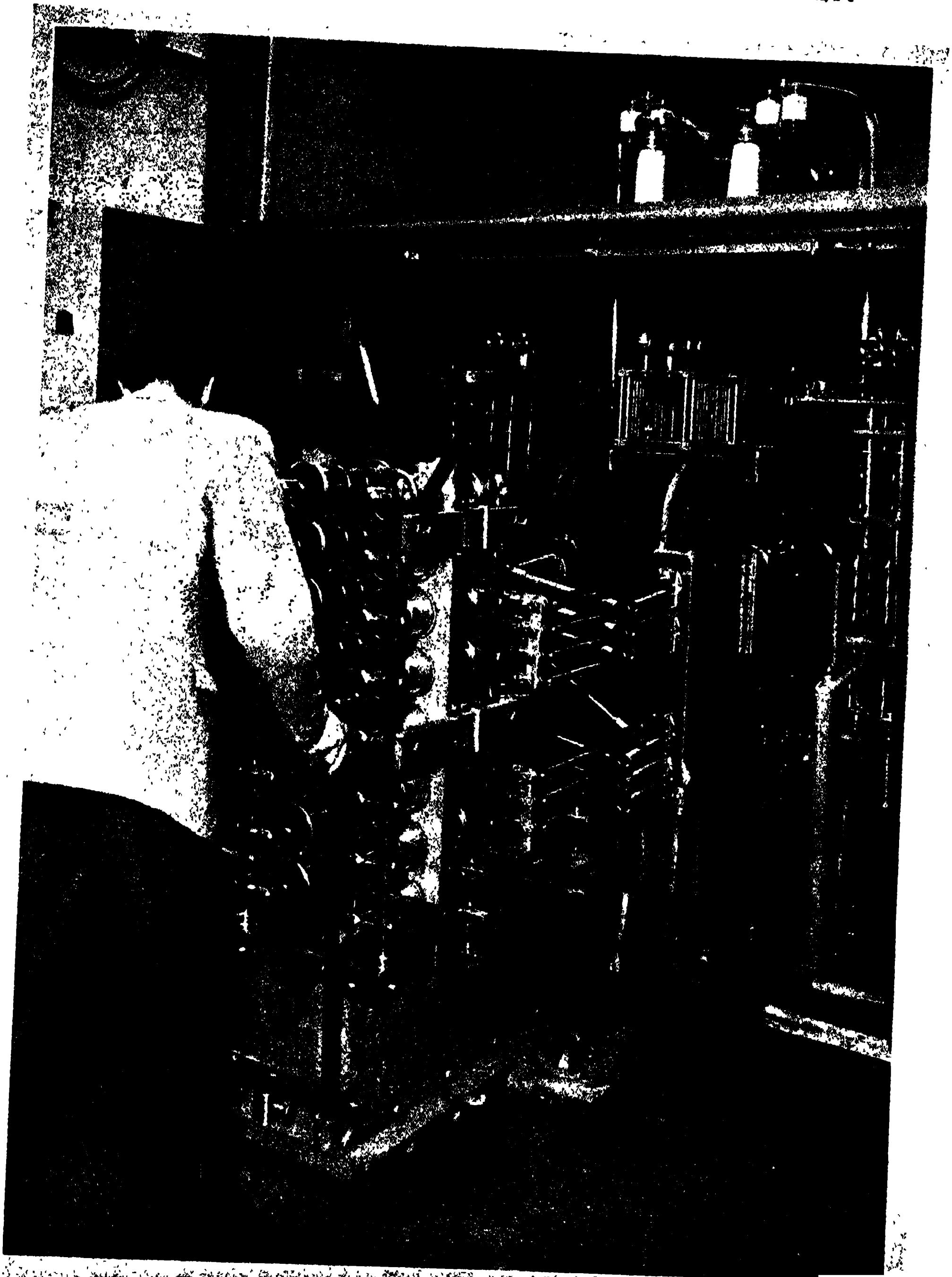
Now the loudspeaker is very much like the microphone: it contains a powerful magnet with a coil of fine wire poised between the poles. Attached to the coil is the diaphragm of the loudspeaker.

When the sound current passes through the speech coil of your loudspeaker the coil begins to move to and fro, or vibrate, exactly in sympathy with the moving coil in the studio microphone. This moves the large diaphragm of the loudspeaker so that it gives out exactly the same sounds as those which are being heard in the studio by the artificial ear, or microphone.

Sight and Sound

Most of us at some time have heard or read the fairy tale about the Princess who possessed a magic mirror. By looking into this mirror she was able to see what was happening at places far distant. The modern television

IN A SHORT-WAVE TRANSMITTER



Marconi's Wireless Telegraph Co.

Some idea of the equipment used in a modern broadcasting transmitter can be gained from the above photograph, which shows a pre-tuned circuit truck being wheeled into place in a Marconi 100 kw. short-wave transmitter. A separate truck is used for each frequency to which it is desired to tune the transmitter so that frequency changing is simply a matter of removing one truck and replacing it with another.

receiver has brought the Magic Mirror of the Princess into actual existence. The development of the present-day television set would make a long and highly technical story. Some brief details of this development will be found in a later chapter "The Magic Mirror." Here we will just say that in the Broadcasting studio a camera, fitted with an electric eye looks at or "scans" the scene which is to be televised. Tiny electric currents are set up in a wire connected with the electric eye and these currents are amplified and broadcast. In the television receiver a wonderful device known as a cathode ray tube is used for reproducing the scene which is being observed by the electric eye camera in the studio.

From Radio to Radar

Long before the 1939 war began British scientists had been working in secret upon a most exciting discovery. It had been found that wireless waves sent out from a transmitting station were sometimes reflected back to the station when they met any obstruction, such as an aeroplane in the sky or a ship at sea. By using a cathode ray tube and connecting it to the transmitter it was found that the tube would show a picture of the wave sent out. It was also found that if the broadcast wave was reflected back from any object it would appear on the screen

B B C.

BROADCASTS FOR CHILDREN AT SCHOOL

Some 15,000 schools listen to one or more of the series broadcast by the B B C in their Schools programme, and this number is steadily growing About fifty broadcasts are given each week, covering a wide variety both of subjects and of age One of the most valued services over a long period has been "Music and Movement" for the younger children by Ann Driver, and in the picture above we see the class learning a new song.

of the cathode ray tube a little distance away from the transmitted wave.

By working on, and perfecting this discovery, British scientists were able to set up round our coasts a number of Radar stations which enabled watchers to see on the Radar screen any aircraft approaching the coasts when they were many miles distant. It will be appreciated that this was of immense importance to us during the war. Modern aircraft fly at about 4–5 miles a minute. Without Radar, aircraft could only have been spotted when they were about five miles away from the coast and then only in a cloudless sky. These enemy aircraft might be flying at a height of about 20,000 ft.

B.B.C.

BIG BEN AND "MIKE"

Many a time you must have set your watch by the deep sonorous notes of Big Ben, which reached your ears from Westminster by means of wireless. Here is the monster bell with the rubber covered microphone in position up above

Our swiftest fighter aircraft required several minutes to climb to that height and without Radar our only way of intercepting bombers would have been to keep many squadrons of fighter planes continually in the air. Now a swift fighter can only remain aloft for an hour or so before it has to return to its base for refuelling, and while it is flying it uses up petrol at an alarming rate, *i.e.*, from 300–600 gallons per hour.

It is no exaggeration to say that without Radar our air defences would have been thrown into chaos if several groups of enemy raiders had attacked at different points simultaneously. Radar enabled our observers to keep a constant check on the German bomber planes, very often from the time they left their aerodromes in France. This advance information was invaluable in enabling us to use our limited supplies of fighter planes to the very best advantage. Without Radar the Battle of Britain would have been lost.

The early work of developing the use of radio for giving warning of approaching aircraft was carried out in secrecy in this country before the war. No doubt, in other countries, particularly the United States of America, research scientists were working on the same problem, but it is true to say that the British equipment in 1940 was far in advance of anything which had been developed elsewhere.

When America entered the war all the results of British discoveries and development were placed at their disposal and there was a free interchange of scientific ideas between the two countries.

Radar and the Submarines

The submarines which were used in an attempt to isolate Britain from other countries during the war had to

WIRELESS IN HOSPITAL AND SCHOOL

To few listeners can wireless be a greater boon than to invalids slowly recovering from illness in the wards of our hospitals. This photograph shows a corner of a hospital ward with nurse and patients listening-in to the broadcast programme.

B.B.C.

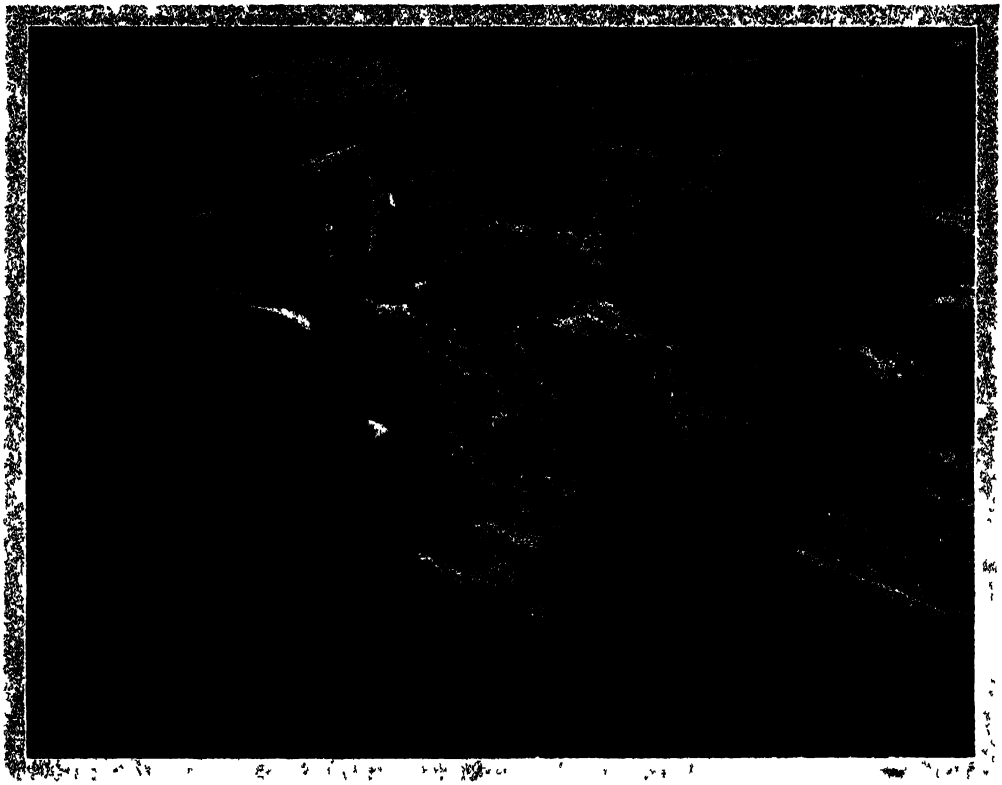
Older scholars as well as the younger children listen-in to their own programmes in the Schools broadcasts The lecturer at the microphone and the school audience co-operate in these senior lessons. Our photograph illustrates a class following a lecture on " Current Affairs," and the schoolmaster is assisting his pupils as the speaker tells them : " Now run your finger round the western bulge of Africa till you find the town of Lagos."

FROM STUDIO TO PICNIC PARTY

Here we have a photograph of the actual scene in the studio during a broadcast of one of the famous " Just William " stories William's good intentions have once again gone astray and his father is confronting William with definite evidence of the damage he has done.

B B C

To the younger generation the miracle of modern radio is not so astounding as to those old enough to remember the first efforts of the London Broadcasting Station (2LO) which began in May, 1922. To-day a portable radio receiver is among the normal luxuries about which it is unnecessary to say much beyond the warning " Don't annoy others ! "



B.B.C.

THE SEA LION MAKES A RECORD

The libraries at Broadcasting House are concerned with many other items besides books. There is, for instance, the Effects Library where special gramophone records giving different sound effects are kept. Here we see one of the sea lions at Regent's Park Zoo kindly recording its vocal efforts in front of the microphone held by the man from the B.B.C.

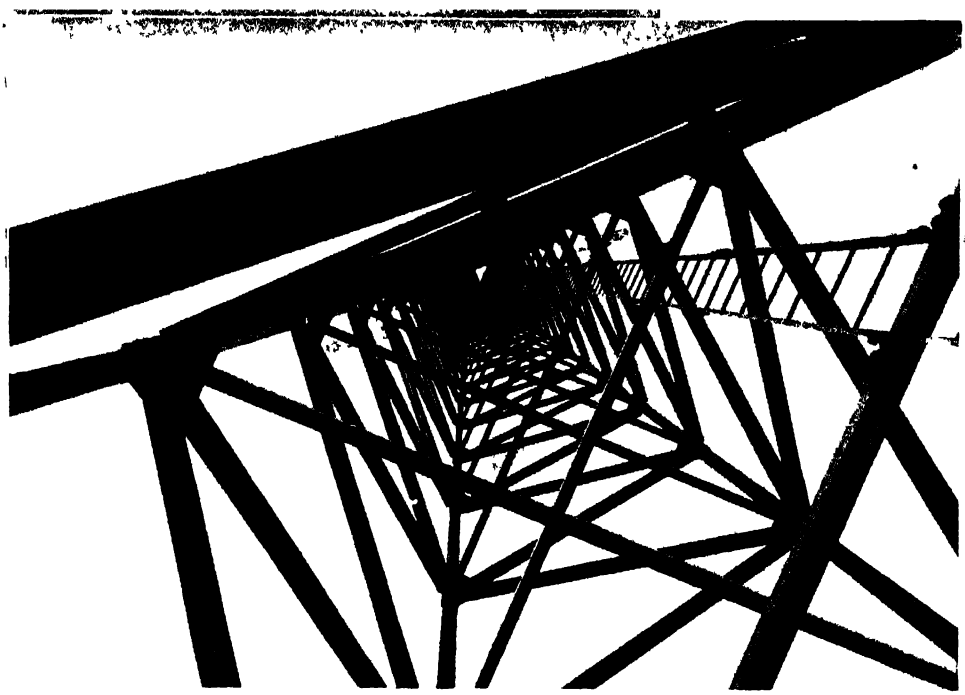
remain submerged during the daytime. At night, however, they came up to the surface, so that they could run their engines to recharge their batteries and also replenish their air supply for the next day. The Germans for a time were very mystified at the number of sinkings of submarines which usually occurred during the night while they were surfaced. The reason was that we were using Radar to detect the submarines.

To-day Radar equipment is being installed for peacetime purposes in ships and in aircraft. By its use ships can steam full speed ahead through the thick fog, because the Captain can be certain that any other vessels in the vicinity will be shown on his Radar Screen when they are several miles away. Aircraft-pilots can use their Radar at night or in fog to obtain an outline of the country over which they are flying and to make sure that they are sufficiently high to avoid any mountains which may lie on their route.

It was through the discoveries made by the wireless pioneers that television and Radar became possible. But radio still remains the great marvel of the present century. The transmission of speech and music by wireless was unknown except to a comparatively few enthusiasts in the years 1920-1922.

Then in 1922, London (2LO) began to broadcast programmes and radio went swiftly ahead. To-day there are some 11 million listeners' licences bought annually in this country.

WIRELESS TELEPHONY



Marconi Wireless Telegraph Co., Ltd

FOR SENDING "BEAM" WIRELESS

This photograph shows what you would see if you stood on the ground and looked upwards inside one of the great masts at the Marconi beam station at Dorchester. An ordinary wireless transmitter sends out waves in all directions equally. With beam wireless the waves are projected in one direction only, as are light rays from a searchlight.

IT was only natural that, by the time wireless telegraphy was fairly on its legs, people should be already thinking of using the waves for transmitting speech.

But they found themselves up against a very difficult problem. One can best understand this by jumping ahead and describing how wireless telephony works.

In Groups of Waves

A broadcasting station sends out what is called a "carrier wave," which is a never-stopping train of waves of exactly the same length and height. These waves are thrown off at the rate of hundreds of thousands a second, and even if they could affect a telephone, they would give a note far too high for the human ear to hear it.

When the "announcer" at the station speaks into a microphone, the waves are "shaken up" by the vibrations of his voice, and broken into groups, each corresponding to one vibration. To get this quite plain, let us imagine the "carrier" to be naturally made up of waves 1 foot long from crest to crest and 1 inch high. The announcer says "Ah-h-h-h." The carrier at once becomes groups of waves. In each group the height of the first wave is almost nothing; the height grows to 3 inches at the middle, and then decreases again. But the length of the waves remains unchanged. Now, the detector bunches all the waves of a group together into what is practically one big wave, and then hands it on to the telephone, which can vibrate in

response to it, and the ear can hear the sound

All sounds treat the "carrier" in the same way, producing bunch waves, as we may call them, of all sizes and shapes. Even when a big orchestra is playing, the "carrier" can carry the note of every instrument on its back and deliver it in a recognisable form This is really very marvellous, is it not ?

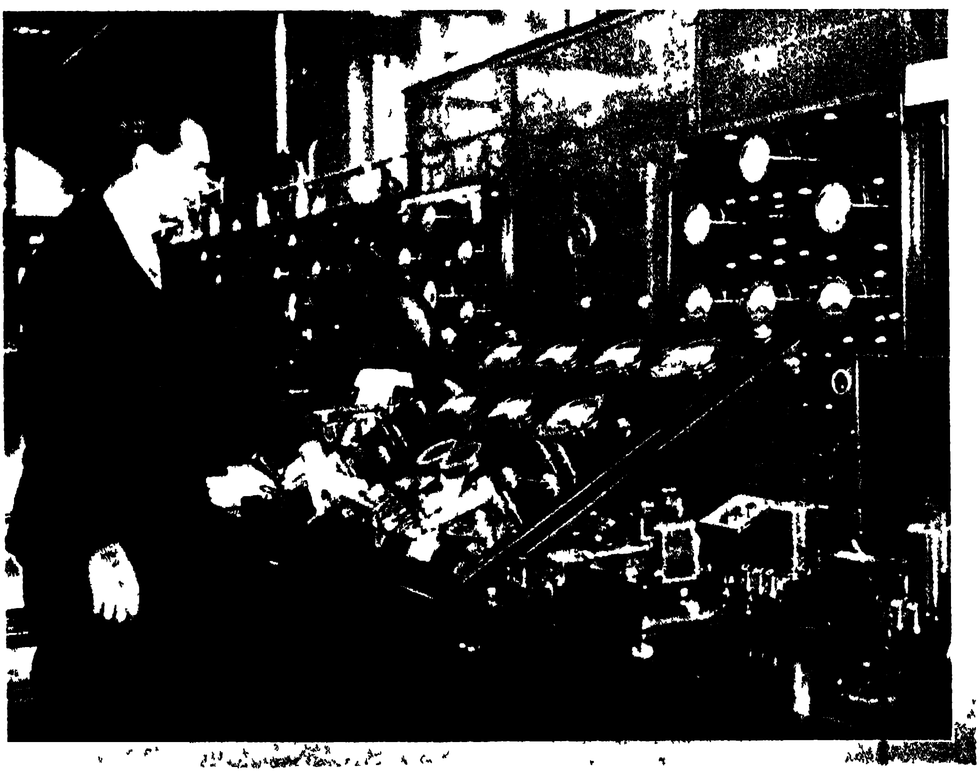
The Problem of the "Carrier"

Now we can get back to the problem wireless telephony required to be solved It was to produce an absolutely steady continuous stream of short waves Various methods were tried, but none of them was satisfactory until the thermionic valve, or vacuum tube, appeared. This very important invention not only sends out a perfect "carrier" wave, but is a splendid receiver of waves, which it also strengthens. By passing the currents from the aerial through one valve after another, they can be magnified to any extent.

Some ingenious person has calculated that the total electrical energy picked up by an aerial during an evening's listening-in is on the average about equal to what a fly expends in crawling ¼ inch up a window pane. Yet the valves are able to take the tiny currents and work on them till a roar of sound comes from the loud-speaker

Speaking to America

Anyone who wishes to talk with a person in the New World is switched on to the great Post Office radio station at Rugby, where miles of aerial wires

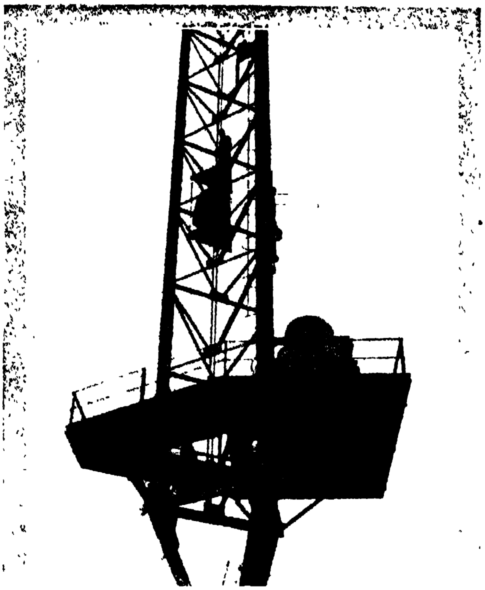


Central Press

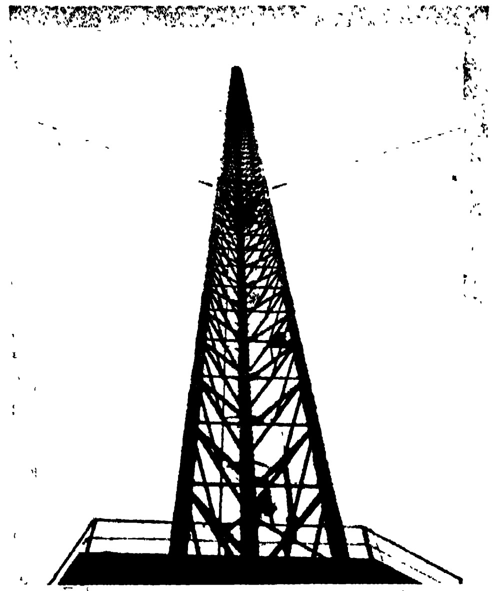
LINKING UP THE WHOLE WORLD

The above print shows us the control table of a world-wide transmitter for sending wireless messages The transmitter is the very heart of the G P O wireless station at Rugby, which both by telegraph and telephone, is in touch with almost every corner of the globe

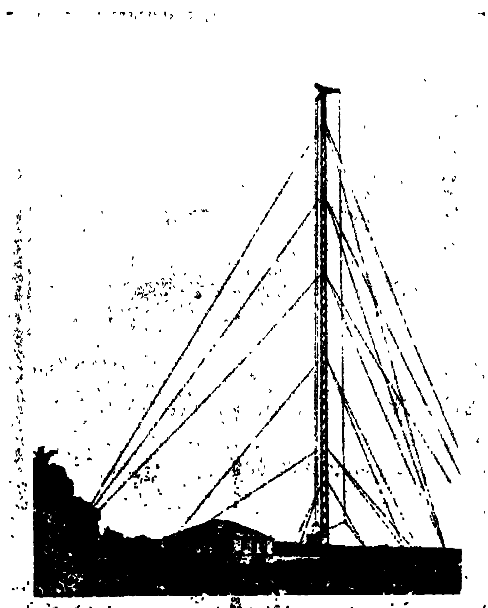
AT THE WIRELESS STATIONS



The masts of the G.P.O. wireless station at Rugby are 820 feet in height. There are no fewer than twelve such masts. Our picture shows the tiny lift by means of which the very summit of one can be reached.

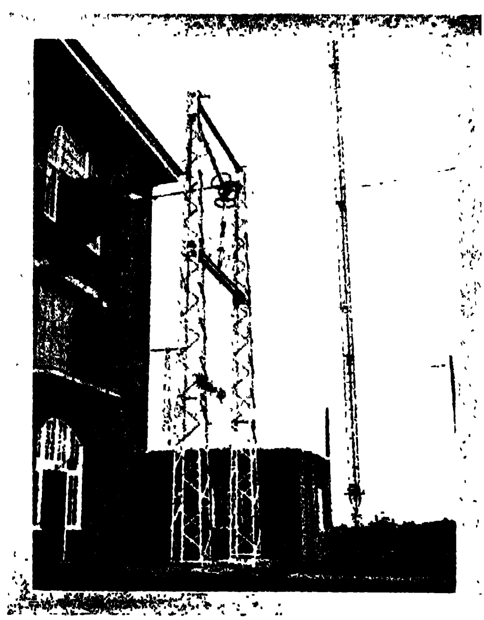


Here is an illustration of one of these twelve monster masts, as it would appear if you stood on the ground and peered upwards. The latticework is of tremendous strength, the wind pressure aloft being terrific.



Marconi.

Here we have one of the Marconi anti-fading aerials, supported by a 150-metre (nearly 500 feet) non-insulated mast. It is in use at the Dorchester Station.



Central Press.

Very likely the wireless set in your home has "leads" coming through the sitting-room window. Here we see the "lead-in" and insulators from the long-wave aerials.

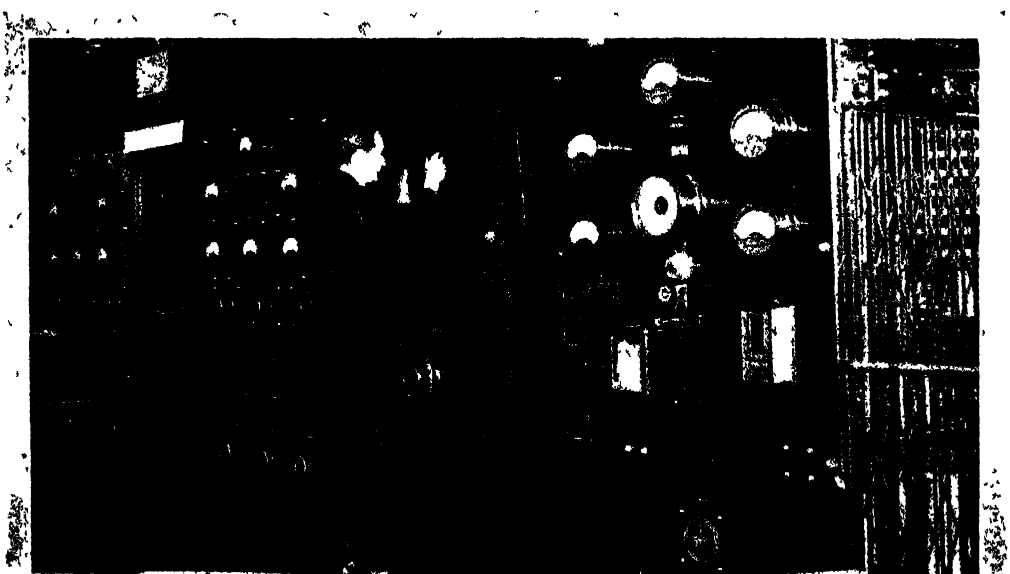
are carried on the top of twelve huge masts, 820 feet high and a quarter of a mile apart. The speaker's voice affects a group of over fifty great valves, and lets loose gusts of electricity equal to more than 600 horse-power. At the same station there is a similar outfit for wireless telegraphy, which now also makes use of the valve for sending messages.

The thermionic valve is a wizard, though to look at something like an incandescent electric bulb, and not at all suggestive of a valve in a pump or engine. It gets its name from the fact that it allows current to flow only one way through it, and in an electric sense shuts if the current tries to flow the other way. The current—in the form of electrons—jumps across a gap between a hot wire and a small metal plate inside the glass, passing through a coil or screen of wire. This is called the grid. It is the secret of the valve's power of magnifying currents, for very little changes in its electric condition produce much larger changes in the current going through the valve. One may compare it to the regulator of a locomotive.

By "Beam" Wireless

We may fitly end up with a few words about one of the fairly recent developments in wireless. Marconi comes into the picture again, with what is called "beam" wireless.

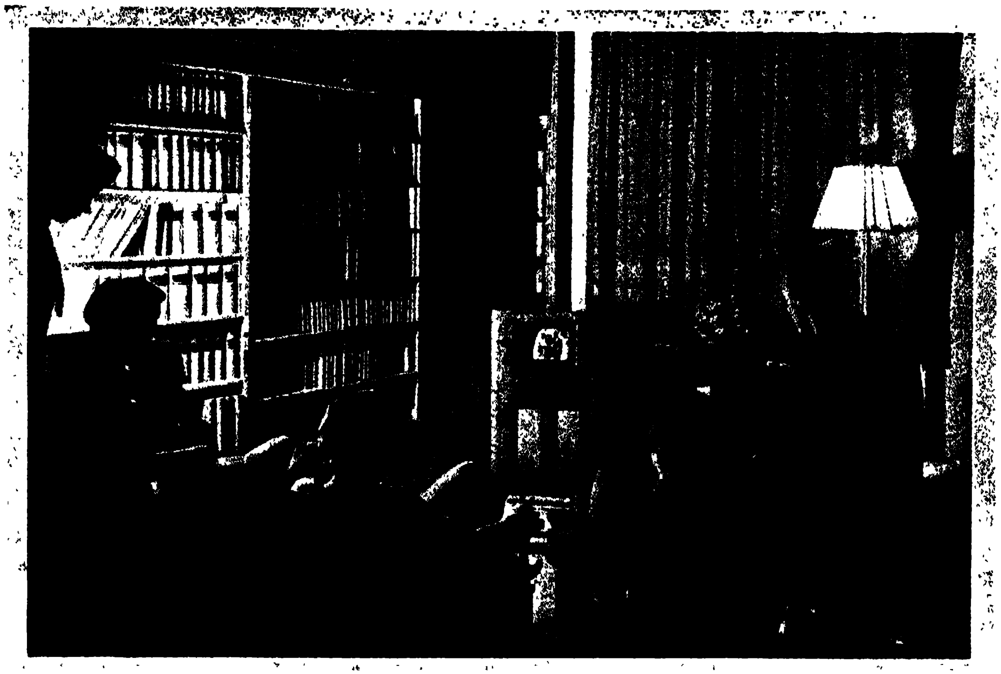
An ordinary wireless station sends out waves in all directions equally. This is all right for broadcasting, but if signals are intended for one place only it means a great waste of power. So Marconi thought out a plan for treating wireless waves as a motor-car headlight or a searchlight treats light. By means of a special kind of reflecting aerial he shot out the waves in the form of a beam all in one direction only. The Empire is now linked up with "beam" stations in England, India, Canada, South Africa, Australia, and elsewhere. The "beam" method has cut down the power needed over 100 times, yet it permits words to be sent and received at the rate of 250 in a minute.



TUNING-IN AT RUGBY G.P.O. STATION *Central Press*

The official here depicted is "tuning-in" the world-wide telegraph transmitter at the great G.P.O. wireless station at Rugby. What an amusing contrast this presents to the very modest task of tuning-in by turning a small knob on one's home receiving set!

TELEVISION—THE MAGIC MIRROR



The General Electric Co. Ltd.

THE MAGIC MIRROR AT WORK

The modern television receiver provides an almost unlimited variety of entertainment, which can be enjoyed in the comfort of one's home. The picture being received is clearly visible in the frame at the top of the receiver.

MORE than twenty-five years ago John L. Baird, who was then working in an attic in Soho, London, constructed the first apparatus to demonstrate that television was practicable.

Television means being able to sit in a cinema or your own room at home and to see on a screen what is taking place in a studio, or on Epsom Downs, *whilst it is actually happening*.

In Mr. Baird's early apparatus, lenses and, later on, mirrors were used for "picking up" the scenes to be televised, but to-day a special sort of camera, called an Emitron camera is used. A photograph of the type of camera now in use appears on another page.

If you examine this picture carefully you will see, coming out of the bottom, a fairly thick electric cable. Inside the camera a stream of tiny particles, called electrons, are moving rapidly over the view which is thrown on to a special kind of plate. This stream of electrons passes across every portion of the plate twenty-five times per second, so you will realise it moves to and fro and up and down at an enormously high speed. When it comes to parts of the plate which are very bright, a comparatively strong current comes out through the cable leading from the camera. When the ray, or stream, is on darker portions of the plate, the current coming out of the camera is less.

The Cathode Ray

Now let us stop for a moment and imagine what happens whilst the camera is in use. The powerful lens throws on to the sensitive plate a perfect image of the scene towards which the camera is pointing. In the meantime the beam of electrons, or

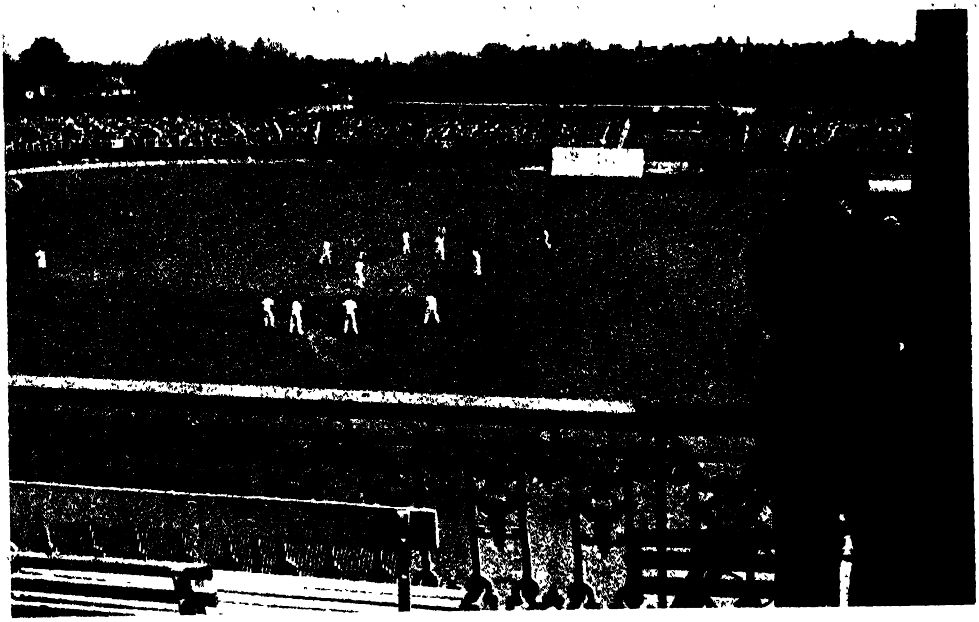
AT THE TELEVISION HEADQUARTERS

The first home of Television in Britain was at Alexandra Palace, and from here the first high-definition Television service began in November, 1936, but had to be discontinued 1939-46. Besides Alexandra Palace there are now other stations at Sutton Coldfield, Holme Moss, Wenvoe and Kirk o' Shotts.

B.B.C.

Here we have a scene in one of the studios at Alexandra Palace. On the stage a performance is being given of the ballet "Les Sylphides," while the Television cameras, the sound-recording apparatus and microphones can all be seen with the operators and producer in the foreground.

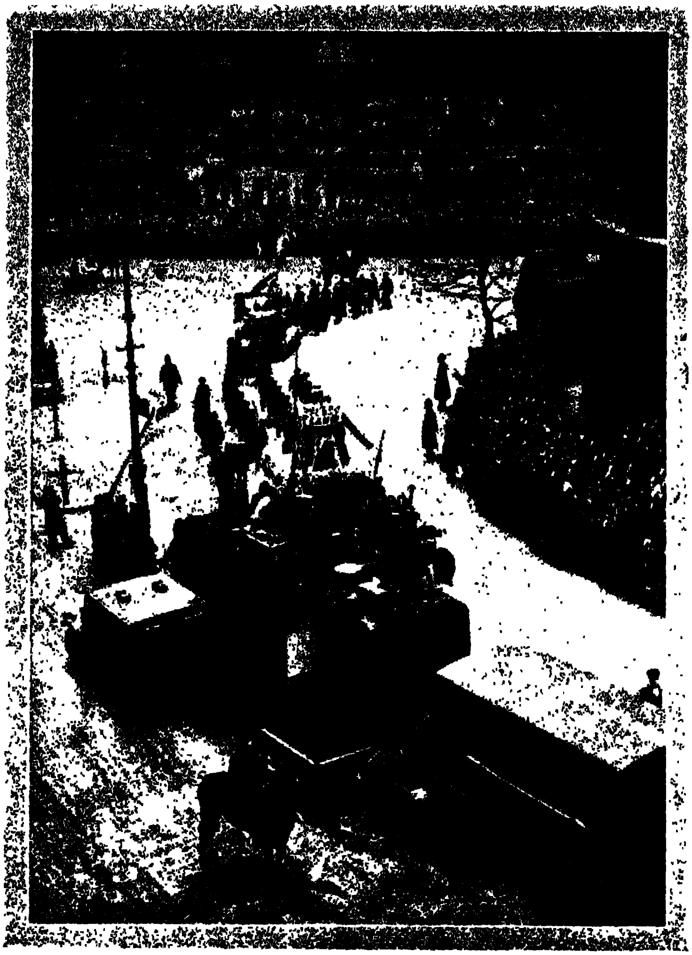
SPORTING EVENTS BY TELEVISION



As the B.B.C. Television Service extended, its use in broadcasting pictures with running commentaries of big sporting events became one of its most popular attractions. In this picture the Television camera is in operation on a balcony at Lords during a Test Match.

B.B.C.

Here we have a different kind of sport, and the Television cameras are again operating to give distant viewers a running picture and commentary of an Ice Hockey match. This photograph was taken at the Empire Pool and Sports Arena, Wembley, during a Cup Final.



B.B.C.

TELEVISING THE LORD MAYOR'S SHOW

Some idea of the apparatus required when the Television Service is in action to record some public event can be gathered from the picture above. The Outside Broadcast Unit is stationed at the corner of Trafalgar Square and Northumberland Avenue to record the Lord Mayor's Show, part of which can be seen as the procession passes the cameras.

cathode ray, as it is called, is sweeping rapidly across the plate exploring, or scanning, every part of it in orderly sequence. Tiny electrical currents, of a strength which varies according to the position of the cathode ray at any moment, are flowing out of the camera through the electric cable. These currents are led to the television sending station, which is very similar to that used for ordinary broadcasts, and so, whilst the camera is in action, wireless waves are being sent out from the television transmitter, and these waves are varied (or as experts call it, "modulated") according to the brightness of each little bit of the picture on the camera plate as the cathode ray passes over it.

From Waves to Pictures

Now let us look at the receiving end and find out how these wireless waves are turned into a picture on the screen of the television receiver.

The photograph at the beginning of this section will show what a television receiver looks like, though many of you will have seen similar television sets in operation. It is similar to a large radio receiver, and it has an oblong opening through which can be seen a greyish screen.

When the receiver is properly tuned in, a picture appears on this screen which is a faithful copy of the scene towards which the television camera is pointing. This is brought about in a way which you will have no difficulty in following, if you have understood the explanation already given of the manner in which the camera picks up the picture.

You will remember that the final result of pointing the camera at the picture to be televised was that a rapidly varying electric current came out of the cable connecting the camera with the television transmitting station. You must now imagine that this current has been transmitted "over the air" and has reached the television receiver.

Inside the receiver is a very ingenious device, which is known as a cathode ray tube. A picture of one of these tubes will be seen on another page, and it is the front end of the tube which forms the screen in the television receiver. You will remember that in the case of the camera, the cathode ray was made to sweep over the *picture* very rapidly. Now, inside the cathode ray tube in the receiver, a similar cathode ray sweeps over the *screen*, keeping exactly in time with the cathode ray inside the camera.

Wherever the ray strikes the screen, the special coating becomes lighted up. Now, whilst the ray is moving over the end of the tube, its strength can be turned up or down. If the strength is turned down, the screen will not light up where the ray strikes it. If the strength of the ray is increased, the screen will become very bright wherever the ray touches it. And now we can see the use of the electric currents which are coming into the receiving set from the aerial.

Through a suitable arrangement of valves the incoming current is used to strengthen or weaken the cathode ray as it sweeps over the surface of the screen. And so, when the cathode ray in the camera is passing over a dark part of the plate, the cathode ray in the receiver is turned down and the corresponding part of the screen is shown dark. Similarly, when the exploring ray in the camera is passing over a

B.B.C. Copyright.

CLOSE-UP OF A TELEVISION CAMERA

The operator is focussing the Emitron camera so that a clear picture will be thrown on to the special plate. The small, varying, electrical impulses are led to the transmitter through the cable shown at the base of the camera.

bright spot, the cathode ray in the receiver is turned on at nearly full strength, and the screen glows brightly at the corresponding spot.

The Second Beginning

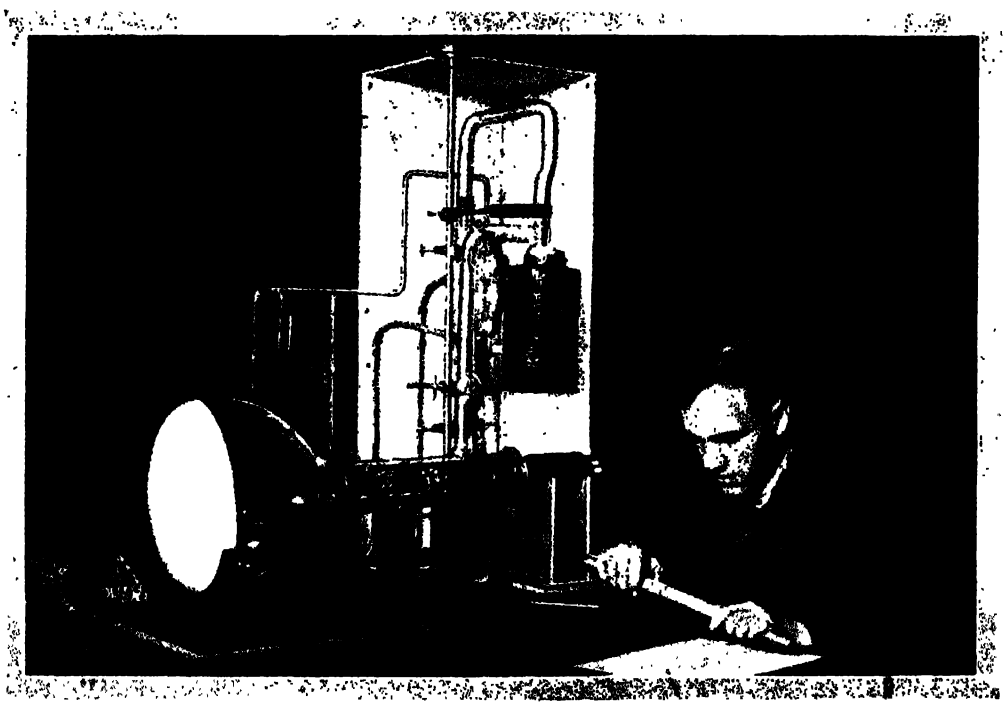
If you remember that all this is happening so fast that the cathode ray travels over the screen twenty-five times per second, you will understand how it is able to build up on the screen a picture which moves and shows all the details which are being viewed by the television camera.

Television as a public service had only just passed its experimental stage when the war broke out in 1939, and for the next seven years the screens of those who had become early owners of television sets were dead and useless.

Then, in June, 1946, the Alexandra Palace studios opened again and the first studio programme was sent out over the air. In less than twenty hours after this studio performance the television cameras were mounted in Pall Mall and viewers in their own homes saw the complete Victory Parade as viewed from a position opposite the Royal saluting base.

It was a complete success and since then, despite the handicaps imposed by the austerity conditions of the times, the B.B.C. television cameras have transmitted a large number of "O.B.'s"—outside broadcasts—from sports grounds and other open-air scenes, besides shows from theatres, dance halls and places of amusement as well as studio performances.

At the end of 1949 a new television station was opened at Sutton Coldfield, near Birmingham, to serve the Midlands. Other stations have now been opened at Holme Moss, Wenvoe (Cardiff) and Kirk o' Shotts (Scotland). Within a few years it is probable that the television receiver will be as common-



The General Electric Co. Ltd.

THE CATHODE RAY TUBE

The tube illustrated is an experimental one, but its appearance is similar to those used for television receivers. The white portion at the end is the screen on which the picture appears, and the cage-like objects in the stem of the tube are used to control the movement of the ray.

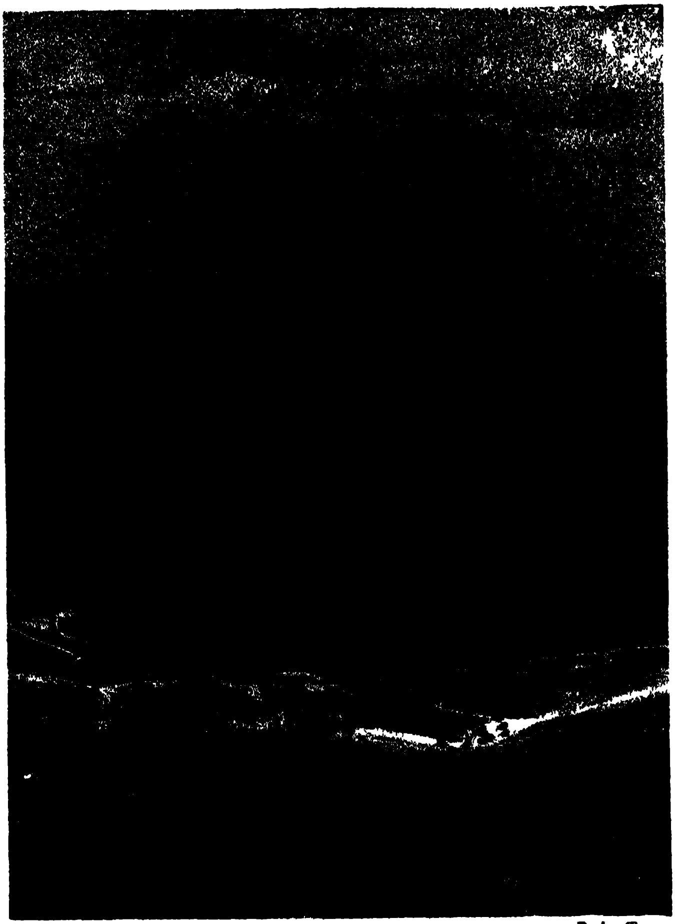
THE TELEVISION MEN IN ACTION

BBC

Here we have a photograph of the Emitron camera with its crew in action televising a play in one of the studios at Alexandra Palace The camera is mounted on a "dolly," not unlike some of those used in film studios, and this can be quickly moved into any desired position

BBC

Here we have a view of Control Room "A" at Alexandra Palace On the left are the engineers who operate the picture shading controls and supervise the general quality of the picture which appears on one of the monitoring screens towards which they are looking The apparatus near them provides the electrical impulses required by the Emitron cameras



Radio Times.

HOLME MOSS TELEVISION STATION

As part of the B.B.C. plans to provide a countrywide television service, a station was opened at Sutton Coldfield in 1949. A similar high-power station was opened in October, 1951, at Holme Moss, and others more recently. This aerial picture shows the Holme Moss station, near Huddersfield.

place in our homes as the ordinary radio set.

Television and Radar

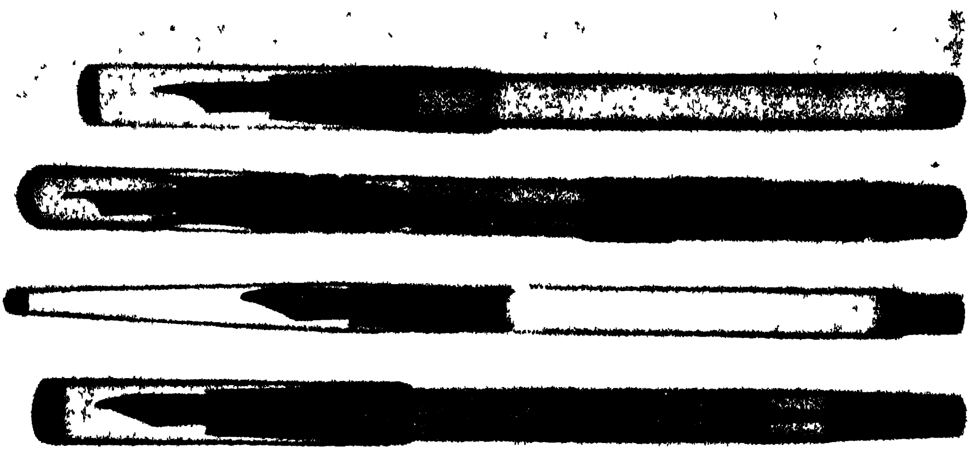
In the sections on "Radio" and "Modern Inventions and Discoveries" the subject of Radar is dealt with more fully, but it may be mentioned here as television has considerable connection with Radar. The cathode ray tube, as we have seen, plays a big part in television, and it is also of the utmost importance in Radar.

The mountaineer who stands on the top of a cliff and shouts across the space to the wall of another cliff so that he receives back an echo, is using the simplest kind of Radar. His voice takes a certain time to travel to the opposite cliff and back again, and by noting the time between the shout and the echo he can calculate the distance.

Radar does exactly the same thing, using wireless waves instead of sound waves. As wireless waves travel with the speed of light, that is, 186,000 miles every second, some very sensitive means had to be found to measure the tiny interval of time between the wireless "shout" and its echo. The cathode ray tube provides this.

In the simplest form of Radar receiver, the screen of the cathode ray tube shows a single bright line. When the transmitter sends out a wireless beam a large kink, like an inverted "V," appears on the line. When the echo is received back from the target a smaller kink appears on the line. The distance between these two depends on the distance of the target. If the target is close at hand the two pips are close together on the screen. If the target is a considerable distance away, the two pips are widely spaced on the screen. The screen is graduated in miles or yards, so that the distance can be read off immediately. The direction from which the target is approaching is determined by using directional aerials for transmitter and receiver.

THE WONDERS OF X-RAYS



Ellison Hawks.

PENS UNDER X-RAYS

An X-ray "shadowgraph" made through a tray of fountain pens. Externally the pens look much alike, but the revealing rays show plainly enough that they differ considerably inside. The bodies of two are empty, one contains a vacuum piston on the end of a thin rod, and the record of the fourth proves it to have a metal lever used in filling the reservoir

IN November, 1895, an announcement of high importance to scientists all over the world was made by Professor W. K. Röntgen, of Würzburg, in Germany. He had discovered a mysterious kind of ray which enabled him to obtain photographs of the internal parts of living creatures.

As Röntgen himself did not recognise the nature of these new rays he named them "X" rays. We know now that these X-rays or Röntgen-rays, as they are often called after their discoverer, are waves in the ether and of the same nature as waves of light, but are very much shorter.

We have already seen in earlier sections that electricity is a flow of electrons through a wire or other metal conductor. Electrons can, however, be made to pass through a space where there is no wire or metal "bridge" for them to cross. If an electric wire is cut the electricity immediately stops flowing because the electrons cannot get across the space between the two ends of the wire. This is because the air is an insulator, that is, it stops the flow of electric current. If, however, these two ends were sealed into a glass tube and nearly all the air extracted from the tube, the electrons would begin to pass across the space, providing a sufficiently high electrical pressure or voltage were applied to the wires.

Probing A Mystery

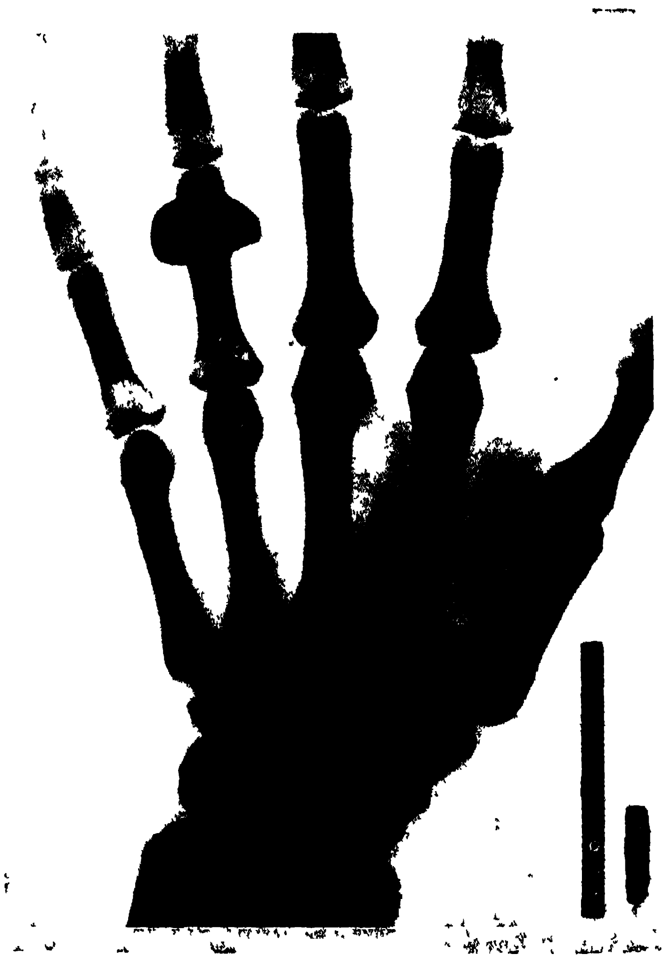
Scientists discovered this fact many years ago and constructed various kinds of vacuum tubes so that they could study the flow of electrons through empty space. It was in the course of experiments of this nature that Röntgen found that if he applied a very high voltage to the two wires entering the opposite ends of the vacuum tube the electrons shot across the intervening space at a very high speed.

Röntgen arranged at the receiving end a target to catch the electrons. This target was made of tungsten. He found that when the electron beam struck the tungsten target some mysterious rays were given off. He

further discovered that these "X" rays would pass easily through many substances which are opaque to light. There were certain substances, however, such as flesh and wood, which they penetrated much better than others, while substances which conduct electricity well, especially metals, resisted the rays. Bone, too, had considerable resistance to the new rays.

By using an X-ray tube and allowing the rays to pass through his hand on to a photographic plate, Röntgen found that he could obtain a photograph showing clearly the bones of the hand. No camera or lens was required, the plate being merely encased in a light-proof envelope and placed on the further side of the object being photographed.

The importance of these new rays was recognised almost immediately, and they have been of incalculable value in surgery, for they practically endow the surgeon with a pair of matter-piercing eyes. If a limb be broken, a photograph is taken through the fracture. On the developed plate the bones appear white, surrounded by darker flesh, while in the positive print made from the negative the tones are, of course, reversed, the bones now appearing almost black and the flesh much lighter. Having the print before him, the surgeon knows exactly what he should do.



International Western Electric Co., Ltd

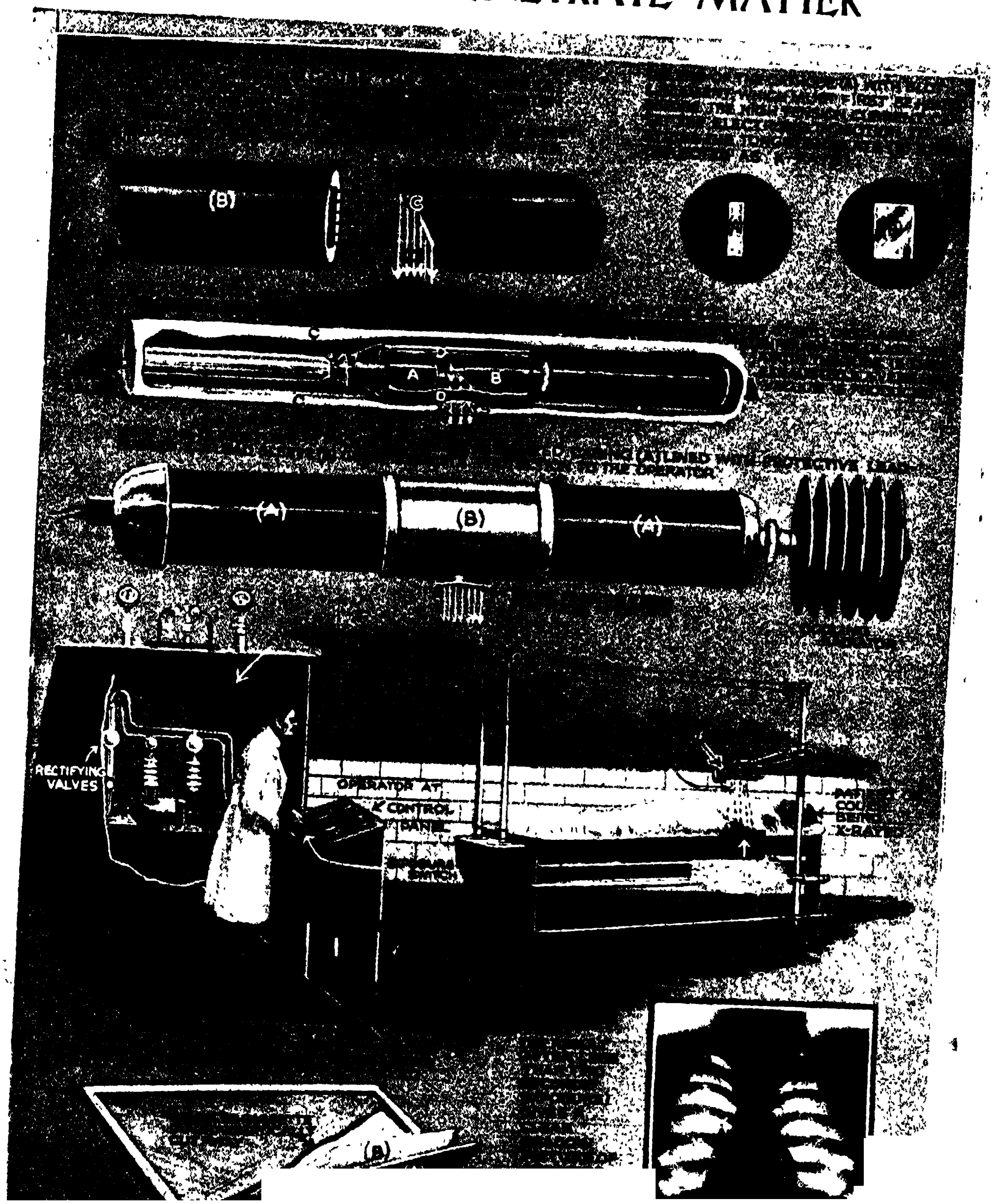
THE FOUNDATIONS OF THE HAND

This photograph, which was printed from a negative "telegraphed" over 931 miles of telephone wires from an original X-ray negative, shows very clearly most of the bones in a human hand. Only those of the little finger are here complete—the long metacarpal bone between the wrist and the finger proper, and the three phalanges of the finger itself. The strange-looking lump on the third finger is a metal ring.

Saved from Death

Or, again, instead of probing about for a bullet buried in the flesh, he takes two or three X-ray photographs in different directions, and by comparing them can fix the exact position of the intruder. Should a person be suffering from an internal complaint, the X-rays are often of great service, for they can show whether the heart, lungs, or other parts are affected. It is not going beyond the

RAYS THAT PENETRATE MATTER



Specially drawn for this work.

The upper part of this illustration describes the construction of the special form of vacuum tube used for projecting X-rays, which are of the same nature as light, but have a vastly shorter wave-length, of about one 250,000,000th of an inch. The rays are created by the "bombardment" of an anti-cathode plate by electrons shot off from a heated cathode plate, which corresponds to the filament of a wireless valve. Their very high frequency enables them to penetrate many forms of solid matter. Metals stop them and that is why the tube is encased in lead, to protect the user.

A PEEP INTO A PENGUIN

The bones of a bird's neck are so jointed that they allow a bird to twist its neck about in a manner impossible for human beings This X-ray picture shows us the vertebræ or neck-bones of a penguin.

truth to say that tens of thousands of people every year owe to these rays an escape from much suffering, and even from death.

X-rays are helpful in many other ways Let us take an example · Expert judges of old pictures were recently much perplexed by a painting said to be the work of the famous Dutch painter, Frans Hals, who died in 1666. One great authority pronounced the picture a genuine "Hals." Others persisted that it was a modern forgery.

The X-rays were called in, and they revealed the fact that the parts of the wooden panel on which the picture was painted were held together with wire nails As this kind of nail was not made till at least two centuries had elapsed after Hals' death, the matter was definitely cleared up.

In a further case examination by X-rays proved that a valuable old picture

Photos Central Press

FLIPPER BONES

And here we see the bones of one of a penguin s flippers or undeveloped wings, useless in the air, but very useful to the bird when swimming under water

AN X-RAY TUBE—

Here is a simple form of X-ray tube The stream of electrons from the right-hand side strike the tungsten target in the centre of the bulb and X-rays are given off.

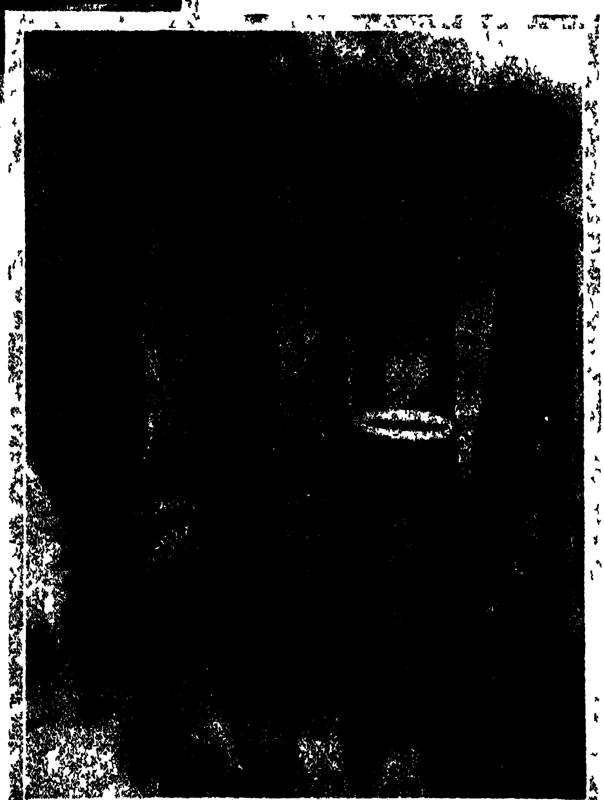
had another and much more modern one painted on top of it.

In the Workshop

The maker of sham jewels has a foe in the rays, for they treat the real and the fraudulent article differently. The maker of electric cables, on the other hand, has a friend in them, since a cable passed between an X-ray tube and a screen at once betrays any metal bodies lurking in its insulating cover. This is a great boon, as even a piece of thin wire in the wrong place may cause trouble. Nor are the rays only useful in finding broken bones and misplaced parts of the body. In certain cases of illness the patient is given bismuth or similar salts to swallow. These salts are not soluble and it is possible by means of X-rays to take photographs of the digestive passages and so find out for certain the seat of any local trouble.

Not only does this save time in bringing relief, but it may prove an operation to be unnecessary.

The X-ray analysis of solid substances proved of the



AND ITS RESULT

These rays pass through the hand and on to a sheet of photographic paper which has been placed downwards on the bench The result of this is seen above the bones and the metal ring were not penetrated and are shown up clearly.

utmost value to doctors, chemists, industrialists and others. Röntgen's discovery also turned the attention of scientists to further investigation of rays and marked the beginning of a new era of wonderful discovery.

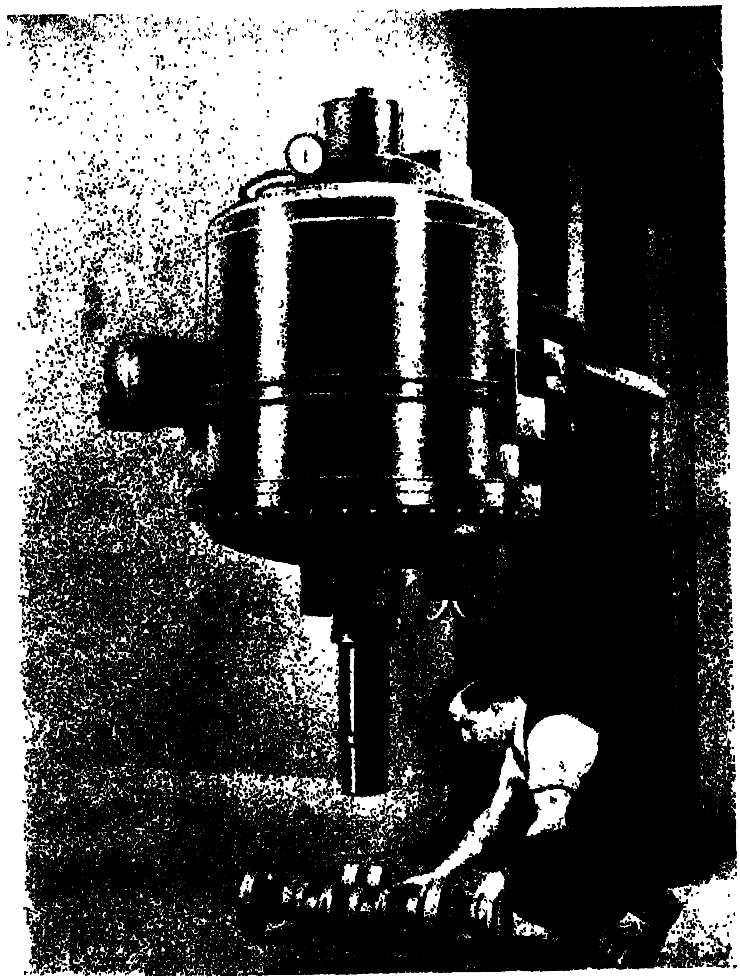
It was from these further experiments that what has been called X-radiation was discovered. In 1896 Professor Henri Becquerel found that a certain compound of uranium emitted a stream of radiation continuously and of its own account. This led to experiments in other directions. Among them were those carried out by Professor and Madame Curie, who searched for other substances having this "radio-activity," as the new property was called.

The result was the discovery of radium. Going a stage further, Lord Rutherford made considerable advances in his experiments on the structure of the atom. To-day the tremendous power of atomic energy has been demonstrated and our hopes for the future rest on its wise use.

The British Atomic Research station at Harwell is already supplying medical men with radio-active substances for the treatment of certain diseases.

Here again we see how the discoveries in one field of science are linked with those in another. Experiments in splitting the atom led to the most terrible weapon of destruction the world has ever known. But it it has also opened up great possibilities in the field of medical science.

X-rays have long proved useful to the surgeon, and in recent years its use in industry has developed considerably. Special X-ray units are employed in big workshops to ensure that important parts of machinery, which will be subject to heavy strain, are entirely flawless.

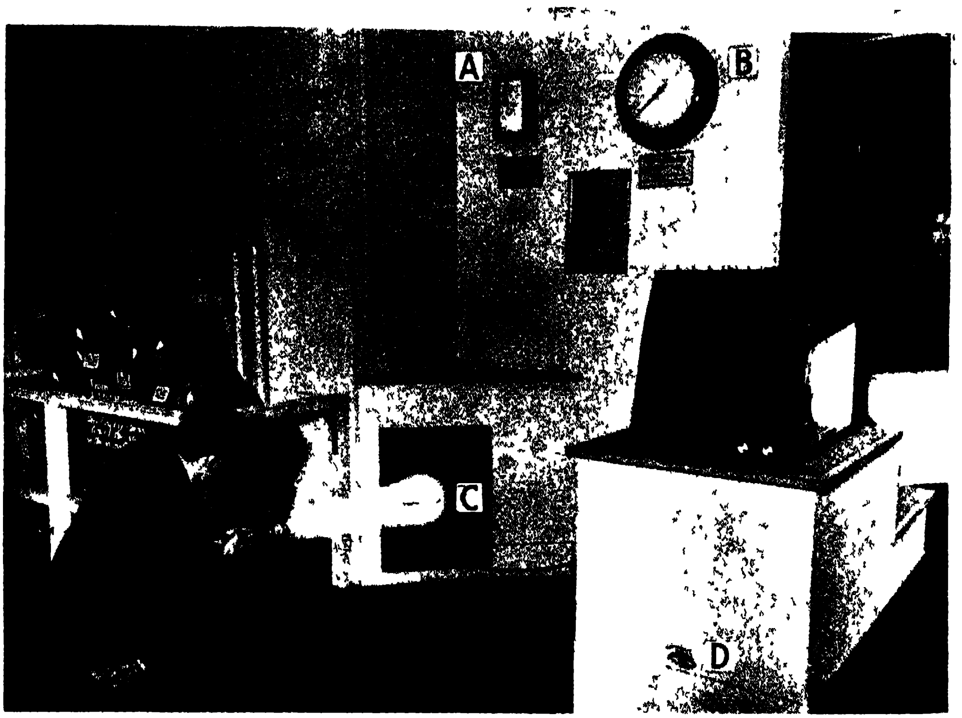


Newton Victor Ltd.

X-RAYS IN INDUSTRY

In this photograph is seen a million-volt Industrial X-ray unit in use in a modern workshop. The operator is placing a heavy casting on the light-proof envelope containing a photographic film. The resulting X-ray photograph will reveal whether the casting is perfect or whether there are any internal flaws which might render it unsafe.

INVISIBLE RAYS



General Electric Co Ltd

TWO USES FOR PHOTO-ELECTRIC CELLS

The extraordinary sensitiveness of a photo electric cell to light, as shown by variations in a current passing through it, is now utilised in many ways. If, for example, a light were thrown on to safe C at night, a burglar alarm A would be brought into operation by such a cell. On the right is seen an "electric eye" that can be placed at the entrance to, say, an exhibition. Everyone passing between it and the light causes the pointer on the counting dial B to move on a step.

AFTER long plotting and planning a cracksman, who is badly wanted by the police for his many successful raids on other people's property, is about to bring off his most daring coup. Midnight struck two hours ago, and here he is in the treasure-house of the great store of Midas Ltd. All round him are thousands of pounds' worth of jewels, fenced off only by the flimsy protection of glass sheets. His diamond will make short work of *them*.

Not a sound is to be heard. The stillness of death broods over the great chamber. The watchmen are about somewhere, but for the moment, at any rate, the coast is clear. Our burglar gets out his tools and, after a careful search for possible tell-tale electric wires, sets skilfully to work.

The Burglar Foiled

Suddenly a slight rustle makes him look up, and, to his horror, he sees several men cutting off his retreat in all directions. The game is up. He will do no more safe-breaking or case-robbing for some years to come.

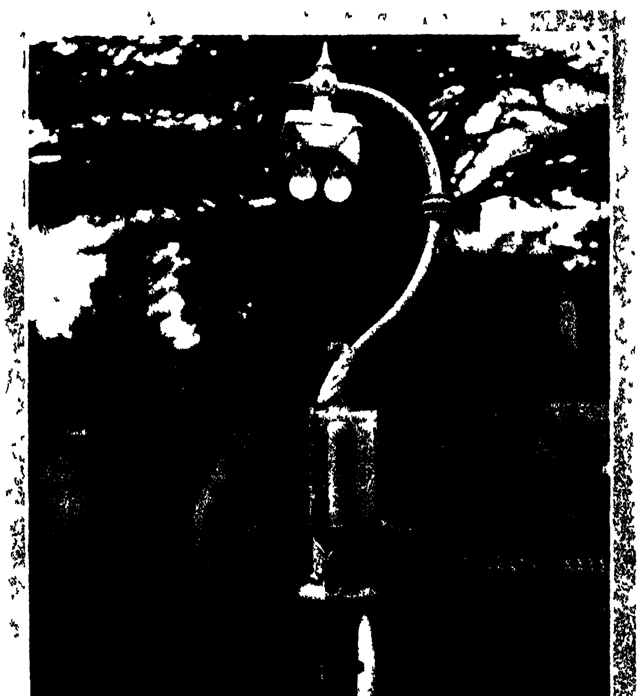
Our burglar is clever; but science and invention are cleverer still. He did not know that at one place he crossed a band of invisible rays, sent out by a hidden apparatus on one side of the chamber towards a concealed selenium "electric eye" on the other. The moment at which he interrupted the

beam with his body was fatal to him. In a distant room a small red lamp on an indicator board suddenly lit up, informing the watchman on duty there that an intruder had entered the jewellery department. A few words were spoken into a telephone, and arrest followed. Science is making life *very* hard for folk anxious to take a short cut to wealth.

Escorted by Warships

Another picture: A great merchant ship is ploughing her way across the Atlantic, bringing much-needed supplies to England during the stress of war-time needs. She is one of a fleet of similar ships being shepherded through a submarine infested area of the ocean by an escort of warships. An officer on the bridge is peering into a kind of telescope, watching the blinking of a tiny screen inside. The sudden short glows of greenish light are signals from the flagship of the escort. Not a sign of light pierces the darkness of the night, yet light is being used to send a message, and it is a message which the commander of an enemy submarine can read neither with his eyes nor with his wireless apparatus.

A mile or two away, on the flagship, there is an electric lamp encased in a special kind of glass, which cuts off all rays that the eye can see. But the infra-red rays find their way through, and on reaching the screen on the telescope they make it glow with fluorescence, as phosphorus glows in the dark, and so the beam radiated becomes visible to the person in charge of the apparatus.



Radiovisor Parent Ltd.

AN AUTOMATIC LAMPLIGHTER

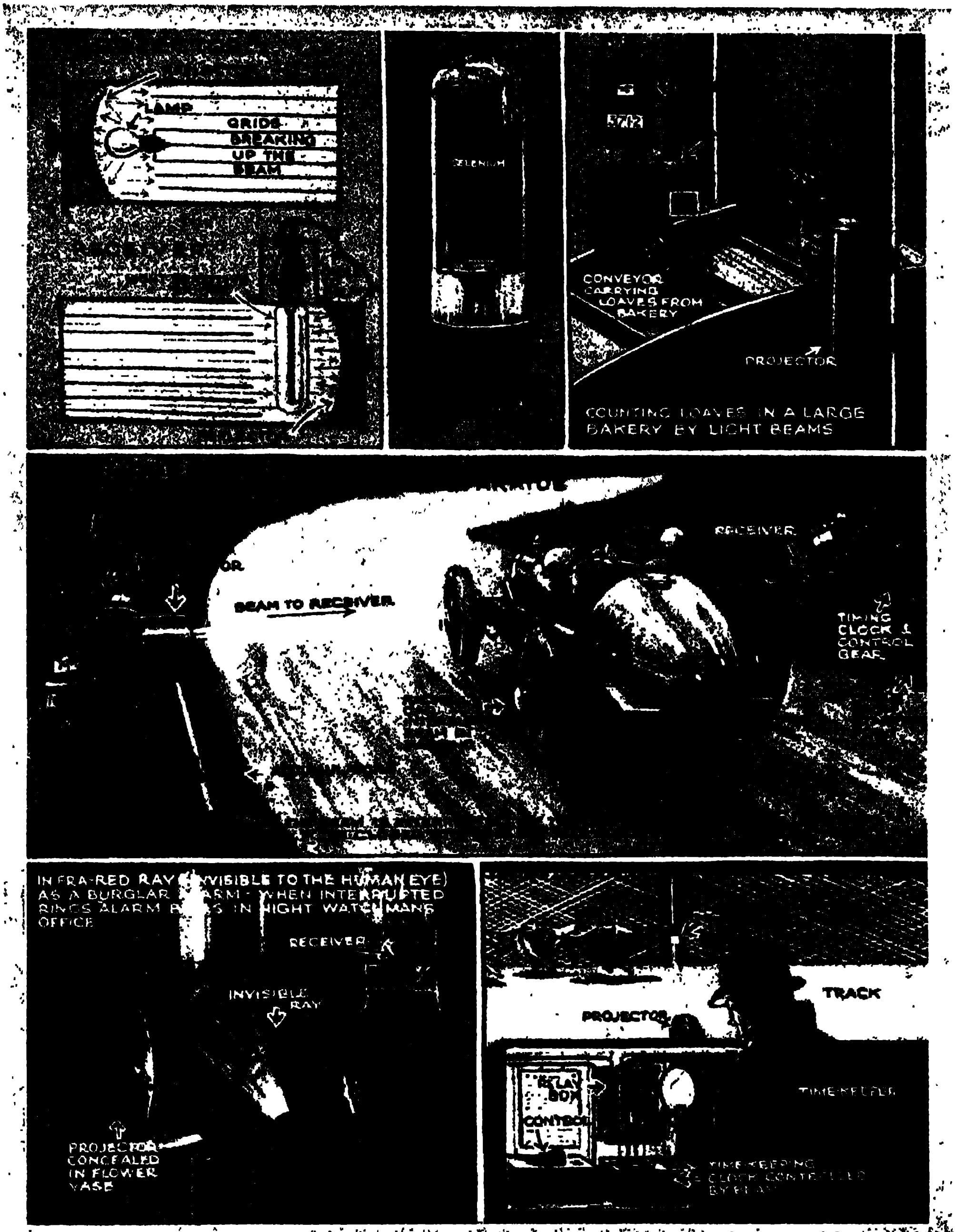
This is the upper part of a street lamp standard at Maidstone, Kent Below the "swan-neck" supporting the bulbs is a casing containing a selenium "bridge" When dusk comes on, the selenium "feels" the lack of light and automatically switches on the lamps At dawn it switches them off again

There are several kinds of Electric Eyes but they all have one thing in common. When light falls upon them electric current begins to flow, or flows in a greater quantity in a suitable electric circuit connected with the "eye."

This electric current can be used to open doors, to operate a counting mechanism, to switch lights on or off (as in some forms of traffic control), or to stop an electric motor driving a large machine.

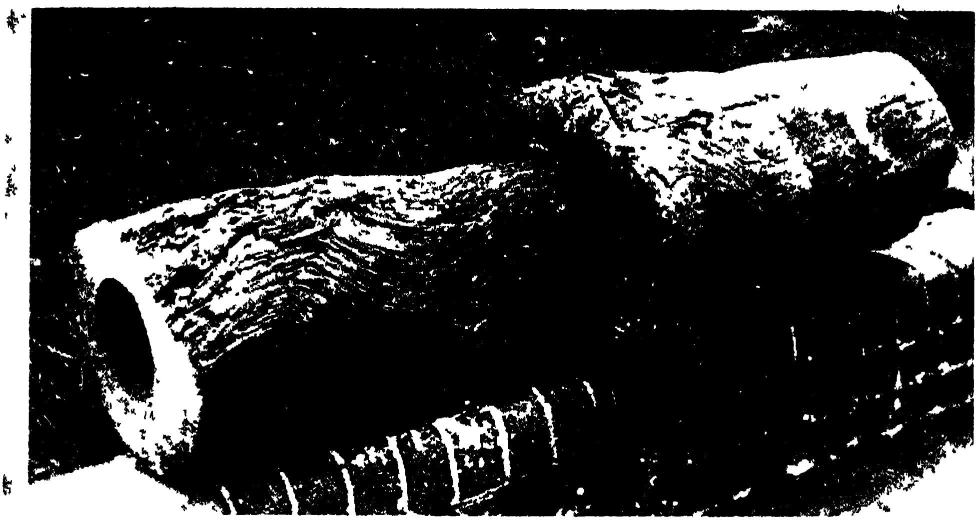
So by selecting the right type of "electric eye" or photo-electric cell and connecting it in a suitable circuit engineers can make doors which open as if by magic when anyone approaches. They can also use a ray of light to guard a safe or to protect a machine operator from accidental injury.

MORE USES FOR "ELECTRIC EYES"



Specially drawn for this work.

At the top are—reading from left to right—an electric lamp specially designed to cast a concentrated beam of light, and a receiver for focussing the beam on to a selenium electric eye ; the electric eye, enlarged ; and the two being used to count loaves passing between them. In the centre is a race-timing apparatus, working on the same principle. At the bottom are shown a similar outfit adapted for greyhound racing, and one for checkmating burglars. In the last case rays which are invisible to the human eye, but can affect an electric eye, are used.



Metropolitan Water Board

THE WATER PIPES OF OLDEN DAYS

Even in the long ago a water supply had to be ensured for people who lived in towns, since water plays so very important a part in our lives. The earliest water mains were not made of iron or steel, or even of earthenware, but consisted of short lengths of tree trunks hollowed out and made to fit into one another telescope fashion. Two such pipes are illustrated above

THE WATER WE DRINK

IN an emergency we can live without many things that are regarded as necessities in our ordinary everyday life, but there are certain needs that must be supplied. We cannot exist without water, for instance. Water is essential to life. Our very bodies are largely composed of water and they demand a continual supply of it. Water is necessary, too, for cleanliness and health.

Every kind of industry requires water, and a good many industries cannot be carried on without a considerable quantity and a continual supply. In the beginning of human history it was to a large extent the question of an adequate water supply which decided the place where the wandering tribes eventually settled. It was the waters of the Nile which led to the beginning of the earliest civilisation.

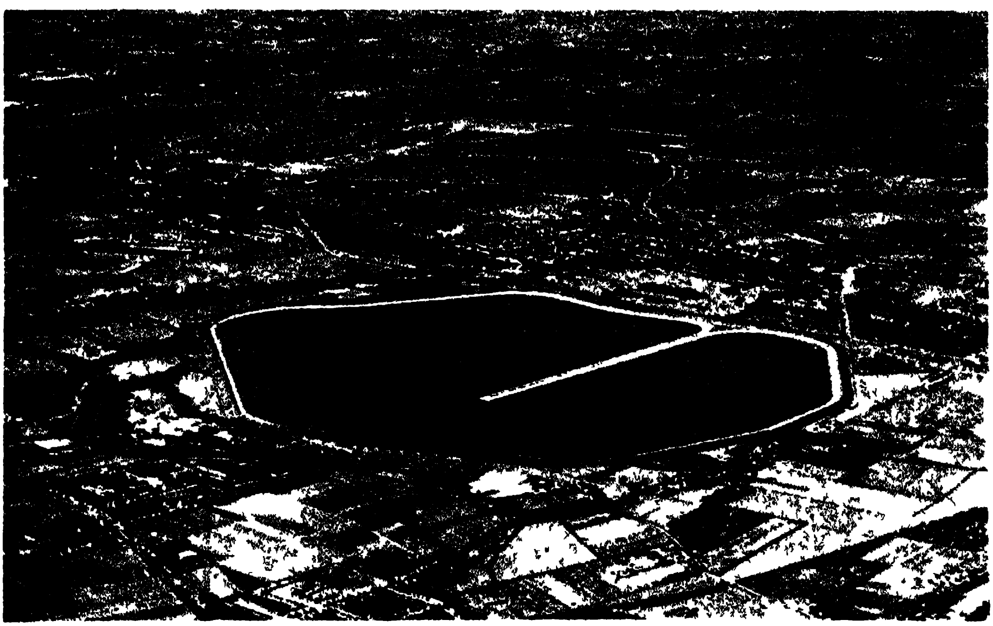
In the Days of the Romans

For drinking and the cleansing of food we must have, not merely water, but *good* water, free from the tiny germs or chemical impurities harmful to the body. Wherever human beings collect in large numbers it becomes difficult to supply them with good water from the neighbourhood. Streams in the near neighbourhood become dirty, and the wells, even if

IN SAMPLES AND IN BULK

Here we see a sample being taken from the filtered water well of a filter bed. All the utensils have been sterilised and expert analyses will be made of the samples taken

Houses near the summit of a hill are often supplied from a water tower on the top of the hill. The water tower seen in this photograph has a capacity of 202 000 gallons



Metropolitan Water Board

This aerial view shows one of the large storage reservoirs into which water is pumped from the river. Its main purpose is to hold a reserve supply of water to tide over a shortage during periods of drought or low river flow. The purpose of the baffle bank seen in the reservoir is to divert the flow of water in a direct line between inlet and outlet and to minimise the waves caused by strong winds

they yield pure water, become insufficient. Either an abundant supply of local water must be made fit for drinking, or good water must be brought to the people from a distance

Two thousand years ago the Romans adopted the second course They led water into Rome and other great cities by constructing artificial channels, called aqueducts, along which the water flowed on a slight slope from some unpolluted source In order to maintain the gradual fall they bored tunnels through mountains and carried the channels across valleys on wonderful lines of arches.

Some of these Roman aqueducts still stand to-day as a monument to the wonderful engineering talents of the great nation that built them. At Nismes, in Southern France, is the great Pont du Gard, spanning a valley with three tiers of arches. This remarkable example of building skill was erected without the use of mortar. At Segovia, in Spain, is another Roman aqueduct, half-a-mile of two-storey arches, standing some 94 feet high Some of these bridge-aqueducts had two or three water channels one above the other, just as in these days we lay two or three pipelines to bring the water from a distant lake to supply the needs of a big city.

Metropolitan Water Board

IN PLACE OF POLISHED TAPS

The above picture, taken from an old print, shows us a water-carrier of London in olden days, who hawked the precious fluid through the streets. His place is now taken by storage tanks, pipes and taps

During the four centuries ending A D. 100, some 350 miles of aqueducts were made to supply Rome The aqueducts entered the city at different levels, and the amount of water led in during the days of the Empire is calculated at over 200 gallons a day for each of the million and a half inhabitants of the capital From large reservoirs in Rome the water was distributed through lead or earthenware pipes to houses, fountains, public baths, and even to the Colosseum, where a great lake could be formed to stage a mimic sea-fight Few cities even in our own times have a better supply than that enjoyed by the inhabitants of ancient Rome

Modern Aqueducts

The engineer of to-day has some big advantages over his Roman predecessors. He can make use of iron and steel pipes able to stand great pressures, while his drills and explosives enable him to bore tunnels much more easily. In addition, modern pumping machinery does away with some of the difficulties the Romans had to overcome in order to ensure that the flow of water should be steadily maintained from the source of the supply to the place where it was needed

If a piece of lead pipe is bent into horseshoe form, with one 'leg' rather longer than the other, and water is then poured into the longer leg, this water will presently flow out of the top of the shorter leg. For enclosed water always finds its own level. So when a modern engineer has to take an aqueduct

Metropolitan Water Board

INTAKE FROM THE RIVER THAMES

At several places on the River Thames there are intakes through which the water is abstracted from the river. Behind this intake, screens are fixed to remove any floating debris, and the water then passes through meters to record the quantity taken. After this it passes along to the pumping station and so on to the storage reservoir.

across a valley he does not build a bridge from side to side, as the Romans did, but carries a pipe down one slope, across the low ground, and up the other slope to a rather lower elevation. The pipes are buried in the ground, or covered up in some way and kept out of sight. Should a river be in the way, the pipe is taken under it, or, possibly, carried across a specially-constructed bridge.

An aqueduct may be of pipes throughout, but generally there is some tunnelling to save distance, as well as some "cut and cover" work. The last means, digging a trench, forming in this a masonry or concrete channel, closed in at the top, and then covering it with the earth taken out. Here and there, at high points, there will probably be what are called "balancing reservoirs." The water flows into them at one point and out at another. They break up the aqueduct into sections and prevent the pressure becoming too great anywhere; and they are sometimes used to supply towns near the route.

London's River and Wells

There is little doubt that when the Romans came to Britain they appreciated the fact that Londinium, because of its ford and converging trackways, was the right place to build a walled city. The natural water supply was evidently adequate and there was no need for them to construct an aqueduct. The Thames, with its tributary streams, together with shallow wells sunk in the gravel near the river, supplied all the water that was required.

Nor was there any anxiety about London's water supply when the Normans came. Thomas à Becket's secretary wrote of London in the reign of Henry II: "On the north are pasture lands and a pleasant space of flat meadows, intersected by running waters which turn revolving mill-wheels with merry din. There are also round about London in the suburbs most excellent wells whose waters are sweet, wholesome and clear, and whose runnels ripple amid pebbles bright."

So long as the sources of supply remained within easy reach, distribution was effected by water bearers or carriers. These water carriers became quite an important guild in the fifteenth century, having the title, "Rulers, Wardens and Fellowship of

the Brotherhood of St. Christopher of the Water Bearers of London." Right down to the seventeenth century they carried on their work, using buckets and sometimes tankards rather like a milk churn. The buckets were carried in pairs as seen in the picture of one of the craft, while the tankards, holding about five gallons, were carried on the back.

All the time London was growing, and conduits, or trenches, had to be constructed to lead the water to the more densely-inhabited districts. There were various schemes put forward for ensuring a communal supply before a wealthy merchant, Hugh Myddelton, put a plan before the City Corporation in 1609 for making a river to supply the city with water from Ware. This New River Scheme was successfully accomplished, though Myddelton was nearly ruined by the undertaking.

However, it is worth recording that Myddelton did not die in poverty but tackled other ventures and restored his fortunes. His services were also recognised by King James I who created him a baronet and excused him from paying the heavy fine, or fees, usually imposed when this honour was conferred.

This New River Scheme, from the point of view which Myddelton had in mind—the supply of water to the community—was a great success. It still plays a part in helping London's water supply but is now fed with water from the River Lee at New Gauge Intake, Hertfordshire, by Chadwell Spring (when flowing) and by water from a number of wells along its course.

Mainly from the Thames

Other Water Companies were formed in London as the city grew. Most of these companies, as well as many of the devices and inventions they introduced,

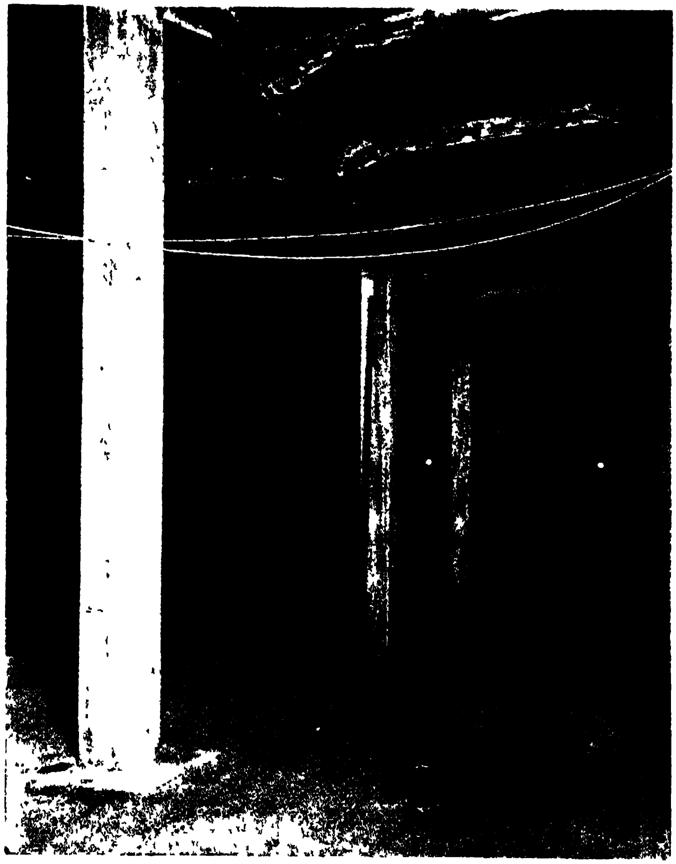
Metropolitan Water Board

OUTLET FROM A STORAGE RESERVOIR

In this photograph is seen the outlet shaft which is approached by a bridge from the bank. A large conduit under the embankment from the bottom of the outlet shaft conducts the water from the reservoir to the aqueduct which conveys it to the distant filtration plant. The concrete lining of the inside slope of the embankment is to prevent erosion by wave action

all contributed something towards the improvement of the city's supply. Eventually all companies were taken over by the Metropolitan Water Board which was established in 1902 and began work in 1904.

To-day London gets some two-thirds of its water from the Thames, and the supply of the remaining third is about equally divided between the River Lea (or Lee as it is sometimes spelt) and from well. The River Lea really supplies the New River, and one of the reservoirs in the Lea Valley, the King George's reservoir, covers some 424 acres.



Metropolitan Water Board

INSIDE A SERVICE RESERVOIR

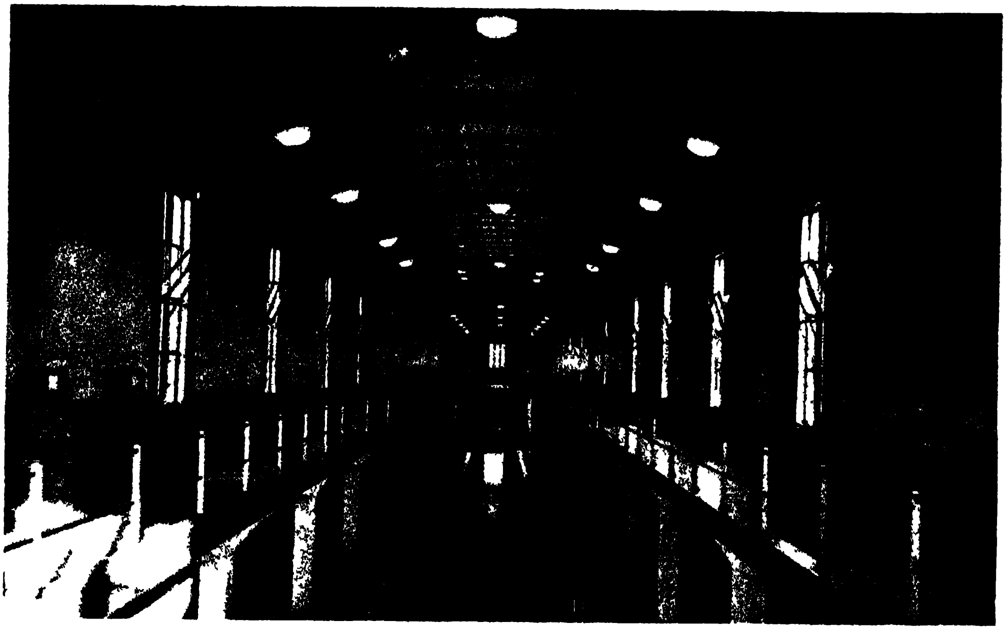
Service reservoirs receive the water pumped in excess of demands, and supply water to consumers when requirements exceed the pumping Here we see one before being filled. Such reservoirs can be emptied for inspection, cleaned and sterilised, and then put into use again.

Thames water is stored in three enormous reservoirs at Staines, covering over a square mile, as well as in the Queen Mary reservoir at Littleton, which is even larger, and twenty-one other reservoirs of varying size. The Metropolitan Water Board supplies daily an average of some 324 million gallons, including 7 million gallons in bulk to neighbouring water undertakings. The area directly supplied covers some 540 square miles with a population of 6½ million people and includes the whole county of London as well as some neighbouring districts. It would require a tank 3½ times the size of Trafalgar Square and about the height of Nelson's column to hold one day's supply of water to London.

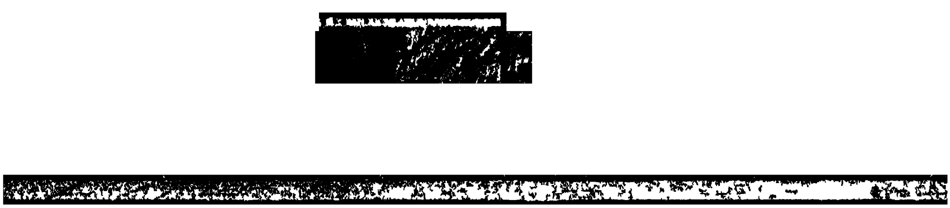
Every gallon of water used in London has to be pumped at least two or three times, and all the water taken from the Thames and the Lea must be purified before it is fit for human consumption. There are some 290 engines at work and they use over 155,000 tons of coal a year, as well as 1¼ million gallons of oil and over 36 million units of electricity. Some of the engines each pump over 27 million gallons of water every day.

The reservoirs in which the water is stored have been made on level ground by excavating material on the site and piling it up all round to form a continuous bank. Altogether these reservoirs hold over 22 thousand million gallons of water. The site for a reservoir must

ENSURING A PURE WATER SUPPLY



Before the water reaches the consumer it passes through various processes to ensure its purity After leaving the storage reservoir it passes through the Primary Filter House seen in the photograph above In this stage the larger suspended matter in the water is removed at a fairly rapid rate before the water passes on to the secondary filter beds

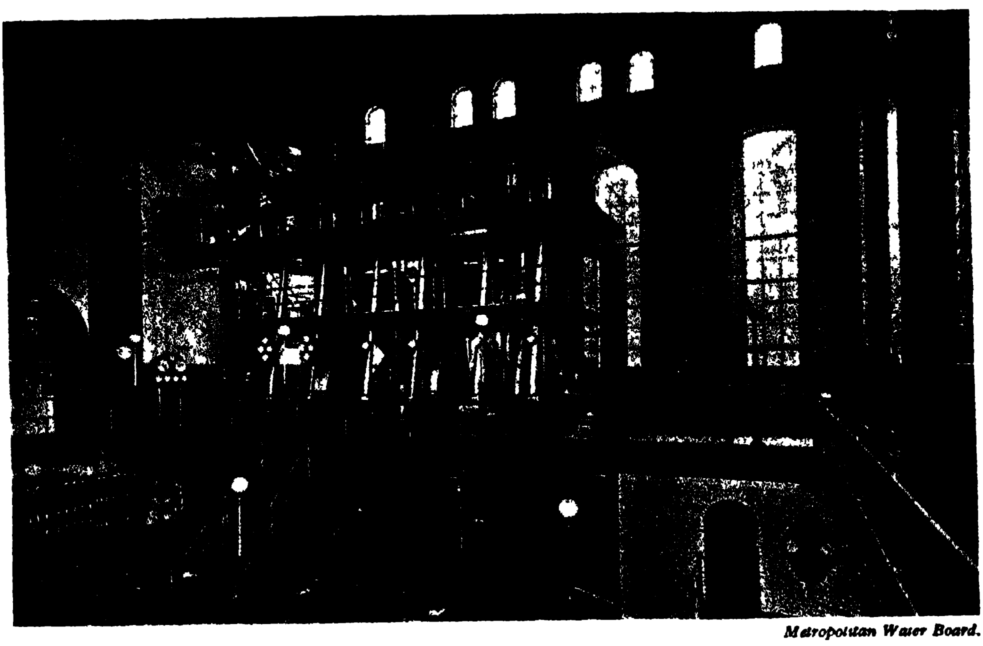


Metropolitan Water Board

Here we see something of the construction of the secondary or slow sand filter bed The water enters through the inlet which can be seen at the far end of the bed, then percolates through the sand and shingle into the tiled drains and is led to the main channel under the floor when it passes to the well at the opposite end to the inlet and is sterilised

FROM RIVER AND WELL

In this photograph are seen the steam turbine units at one of the large pumping stations This supplies a number of zones in the London area with water The water dealt with here has been chlorinated and filtered and is then pumped through large diameter mains to service reservoirs situated on high ground, and from these many thousands of consumers receive their supply



Metropolitan Water Board.

The Thames supplies some two-thirds of London's water requirements, but quite a considerable amount is also obtained from deep wells or boreholes Our photograph shows a well pumping-station capable of pumping some 12 million gallons of water a day A certain amount of water derived from the river is delivered to this station to supplement the quantity obtained from the well

Liverpool Corporation

THE OLD FALL WELL

At the beginning of the eighteenth century the only sources of water supply in Liverpool were springs and shallow wells. The principal supply was obtained from a public well known as Fall Well. Women carried the water from this well in tin cans borne on their shoulders. Later, carts were used for carrying the water and the cans were still employed to distribute it.

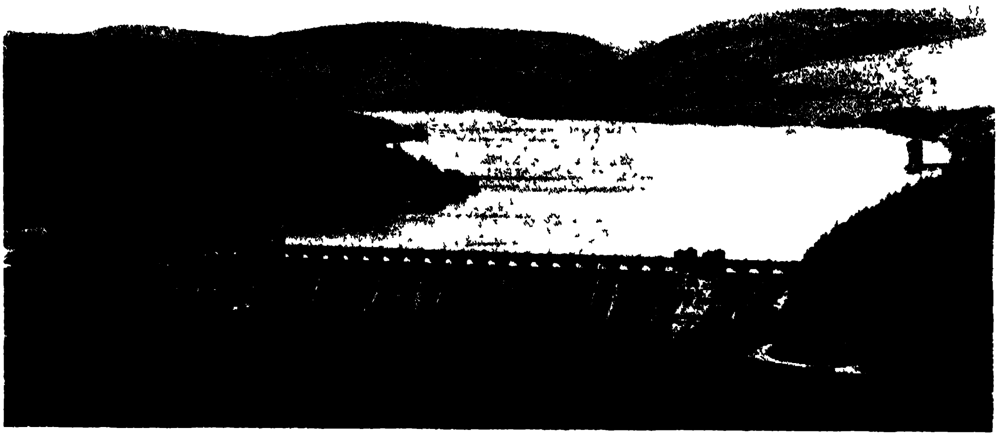
have a thick stratum of London clay underlying it. A trench is excavated on the centre line of the bank down to the clay and keyed into it. It is then filled with puddle clay which is afterwards continued upwards with the bank thus forming a clay puddle wall, and so a watertight basin is formed.

While the water is in these storage reservoirs it deposits much of the solid matter it contains and is to a certain extent purified by the reduction of disease-producing bacteria. After circulation in the reservoirs, water is passed to the filtration plant. At one time slow sand filters were employed by themselves, but to-day the water for London goes through a system of double filtration, consisting of roughing filter beds in the first place and secondary or slow sand beds afterwards. The primary or roughing filter beds supply partly filtered water to the slow sand beds, the output of which is in consequence considerably increased. Photographs of these primary and secondary filters are seen on page 242.

The water percolates slowly downwards through the sand and gravel of the secondary filter beds, and leaves on the surface any suspended matter which may have been in it. The water now receives a small dose of chlorine, the dose varying according to several conditions. Large tanks, known as contact tanks, hold this chlorinated water for a period up to two hours, thus enabling the chlorine to do its work before the water leaves the works. After this the water is pumped through an intricate network of underground mains and does not see daylight again until it is turned on at the tap.

The mains through which the water is distributed are made of cast-iron or steel. The pipes range from 4 inches to

FROM LAKE VYRNWY TO LIVERPOOL



Stewart Bale

Between 1890–1905 the upper valley of the River Vyrnwy in Montgomeryshire, Wales, was converted into a lake by the construction of the dam seen in the photograph above. When it was completed it was for a time the largest artificial reservoir in Europe and the first in Gt. Britain in which a high masonry dam was employed. The length of the lake is nearly 5 miles and it holds over 12,000 million gallons.

Illigraph Ltd

It was not until 1847 that Liverpool Corporation became responsible for supplying the city and neighbourhood with water. From that time on it became a difficult problem to keep the supply adequate for the ever-growing demands. Among the schemes carried out has been the construction of Lake Vyrnwy and the pipelines necessary to convey the water from the Welsh lake to the great storage reservoirs at Prescot, near Liverpool, seen in the photograph above.

48 inches across inside. The largest distribution mains throw off smaller branch mains, and these still smaller branches, and so on. There are also a number of service reservoirs on high ground in various parts of London and these ensure a regular supply of water at all times.

At different points along the mains are valves for cutting off the supply, as well as standpipes and connections for use in case of fire. A street main supplies all the houses in the street, each house having its separate turn-off valve. The length of the mains used in London is over 8,000 miles.

Taking Away the Waste

There is another aspect of the water question which has in the years gone by been just as great a problem as the water supply, and that is the disposal of the surplus and used water. When you have had your bath, out comes the plug and away goes the water. Where? Or again there is a heavy rainstorm and for a brief space the streets almost become a river. An inch of rain is equal to 101 tons, or 22,635 gallons of water per acre of surface on which it falls.

The original sewers of London were designed to carry off rain-water only and it was not until 1874 that a really comprehensive scheme was planned and tackled in a scientific way. It has since been enlarged and the area drained increased, but the general principles remain the same. A great part of the sewage and rainwater has to be pumped from one point to another. The largest

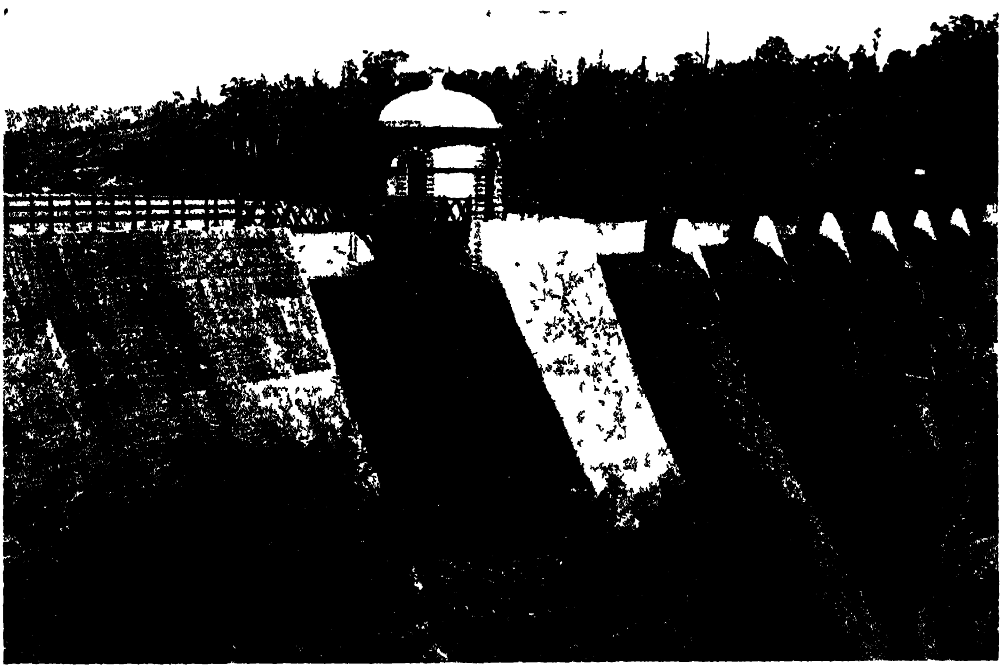
Stewart Bale.

BENEATH THE MANCHESTER SHIP CANAL

Throughout the whole length of the 68 mile aqueduct which brings the water from Lake Vyrnwy to the city of Liverpool there are many crossings over or under rivers, railways and canals. In the photograph above the pipe-lines under the Manchester Ship Canal are seen in their brickwork tunnel, 12 feet in diameter and at a depth of 63 feet below the surface

TWO AUSTRALIAN WEIRS

The waters of the 1 500 mile Murray River have been harnessed by river works which cost £12 000 000 Our photograph shows No 3 Weir one of six similar installations on this great South Australian river These reservoirs supply the life stream of the rich irrigation settlements in the States of Victoria and South Australia



Photos Australian News and Information Bureau

One of the problems which has at times demanded urgent action in Australia has been the supply of water to the gold fields The photograph above shows Mundaring Weir near Perth Western Australia From this weir a pipe-line takes water to the Kalgoorlie and Boulder gold fields, in the Coolgardie district, 350 miles away.

Abrahams Ltd

BEFORE THE LAKE WAS RAISED

When first the proposal was made to use the water of one of the English Lakes to supply the needs of Manchester, there was strong opposition, but eventually Thirlmere was supplying an average of 50 million gallons per day. Later, Haweswater was linked up as an additional source of supply. Our photograph shows the countryside before the lake was raised by the construction of a dam across Haweswater Beck.

pumping stations are at Abbey Mills where there are pumps capable of dealing with 2,000 tons a minute. At Hammersmith is a station which can raise a thousand tons of rain-water from storm-relief sewers and pour it into the Thames.

Every city, town and village in Britain has in comparatively recent times been compelled to tackle this problem of water supply. In Liverpool, for instance, at the beginning of the eighteenth century the only sources of water supply were springs and shallow wells. The principal supply in the town was obtained from a public well known as Fall Well, not very far from where St. George's Hall now stands. The water was carried from the well by women who bore the water-filled tin cans on their shoulders.

Later, as the population increased, carts were used for carrying the water, and the cans were still used for distributing it from the carts. Other plans were put forward but nothing was done until 1786 when an Act of Parliament was passed which enabled the Town Council to supply the district with fresh water. Then companies were formed but the supply they gave was very inadequate. The water was only turned on in the mains two or three times a week and then only for two or three hours. If a fire broke out it probably meant waiting for an hour or two before any water at all could be obtained

Removing a Village

A real beginning was made in 1847 when the Corporation became solely responsible for supplying the city with water. In 1880 they obtained authority to take water from the River Vyrnwy in North Wales and in July 1891 water was first sent through a temporary line of 12-inch steel pipes for a journey of 68 miles from the artificial lake which had been constructed right through to the city of Liverpool. At the time Lake Vyrnwy was the largest artificial reservoir in Europe and the first in Great Britain in which a high masonry dam was employed.

While this new lake was being constructed a whole village had to be destroyed. Houses, school and church were all pulled down and rebuilt below the great dam which was built. Since it was first made, Lake Vyrnwy has gradually increased its supply to the city, and the construction of a fourth pipeline was begun in 1947.

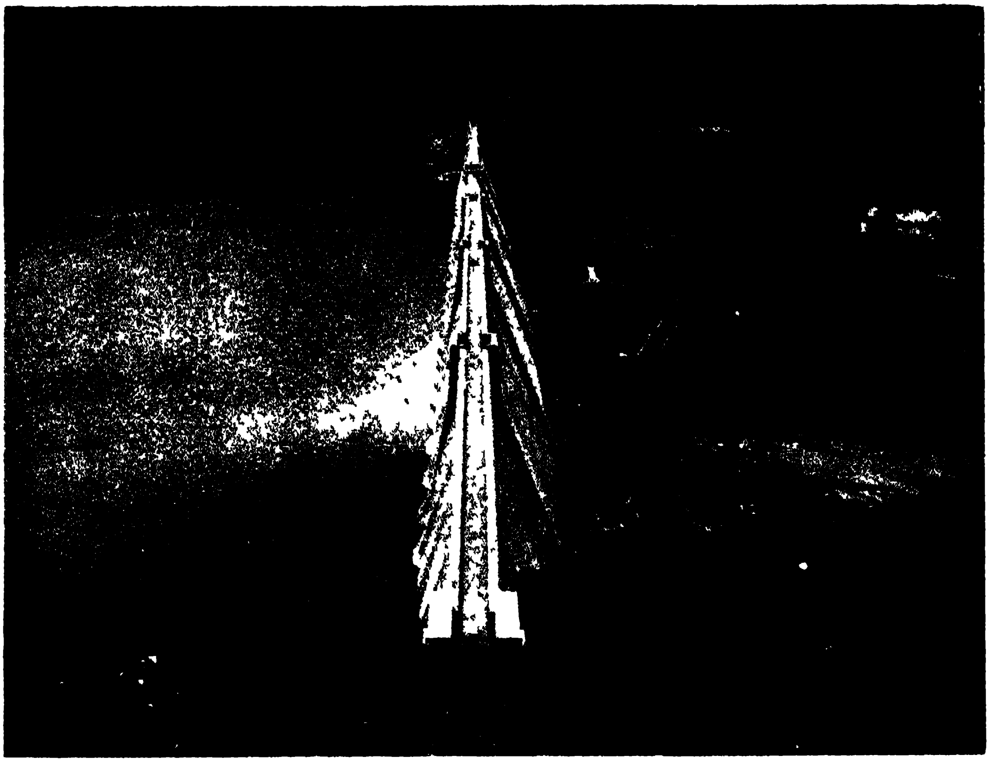
Another city which has had to go a long way for its water supply is Manchester. It first sought for water in the Longdendale Valley in the Pennine Range, some 18 miles to the east of Manchester. The first instalment of water from this source was delivered in 1851, but the construction of the whole works extended over a period of 40 years.

Long before it was completed Manchester realised that with a rapidly increasing population the plans they had in hand were likely to fall far short of what was necessary They went as

Abrahams Ltd

AFTER THE DAM HAD BEEN CONSTRUCTED

In this photograph we have the same view of Mardale Head and Harter Fell taken after the construction of the dam across Haweswater Beck This new source of supply was completed in 1941 Water for Manchester and some of the towns through which the pipe-line passes can now be drawn from either Haweswater or Thirlmere The water surface area of the lake was increased from 346 to 974 acres



Courtesy Manchester Corporation

HAWESWATER DAM JUST AFTER COMPLETION

This photograph, taken just after construction had been completed, shows the great dam at the north-east end of Haweswater It is 1,550 feet long and its maximum height is 120 feet The length of the lake was increased from 2½ miles to 4 miles as the waters gradually rose and spread over a wider area to form a reservoir holding 18,662 million gallons of water to supply the needs of a city 80 miles away.

far afield as the Lake District and at the time there were strong protests on the ground that if their plans were carried out they would ruin the beauty of the surroundings.

From Thirlmere and Haweswater

They were carried out, however, and even the objectors agreed later that the beauty of the district was in no way impaired. The aqueduct which brings the water from the Lake to the thirsty citizens of Manchester is 96 miles long. Eventually even Thirlmere could not meet all the requirements of the still growing city and in 1919 a Bill was passed enabling the city of Manchester to purchase Haweswater, the highest of the English lakes

Some idea of the work involved can be gathered from the fact that the first water from Haweswater to reach Manchester through the Sprint Siphon and Thirlmere Aqueduct was in October 1941. Haweswater is 80 miles from Manchester. By the construction of the dam across Haweswater Beck the water level of the lake has been raised 95 feet and holds a supply of over 18 thousand million gallons.

When eventually the full scheme is complete Haweswater will supply about 72 million gallons per day for Manchester and other towns near the route taken by the great aqueduct. For not only is Manchester itself drinking Lake District water; in the Act which gave the city the right to do so it is also

laid down that certain other towns shall be entitled to obtain their supply from the same source. Broadly speaking, the towns entitled to this are those which lie within five miles of the Thirlmere or Haweswater aqueducts.

The fears which, not unnaturally, many people have had in the past that the construction of mighty dams and the schemes for impounding the waters of a pleasant lake or river will destroy the beauty of the district have actually been falsified by the results. In no case, perhaps, is this more evident than the Elan Valley, from which source the city of Birmingham draws its water supply by means of an aqueduct 74 miles long.

The Elan rises in Cardiganshire and then flows south-east through Radnorshire and Brecknockshire until it enters the Wye. The watersheds of the Elan and its tributary, the Claerwen, were acquired by the Birmingham Corporation and three reservoirs have been constructed on the Elan to impound its pleasant waters for the benefit of Birmingham residents.

This supply was greatly increased by the opening of the Claerwen Dam, the highest in the British Isles, by H.M. Queen Elizabeth II on October 23rd, 1952.

Water for New York

When it comes to a question of quantity New York can claim to use more water than any other city. The aqueducts which bring water to this, the second largest city of the world, are the biggest ever constructed. The first of New York's sources of supply is the Croton Reservoir, thirty-five miles north of America's chief city. From this reservoir well over 300 million gallons of water are brought daily.

This reservoir was formed by blocking the course of a river with a dam that is, next to the Pyramids of Egypt, the greatest of all masonry structures.

Fox Photos

A RESERVOIR IN THE ELAN VALLEY

Here we have a view of the source of Birmingham's water supply from Mid Wales. This shows the bridge over the Elan with the Caban Coch reservoir and dam some little distance beyond the bridge. The city's water supply from this area has been doubled by the Claerwen dam.

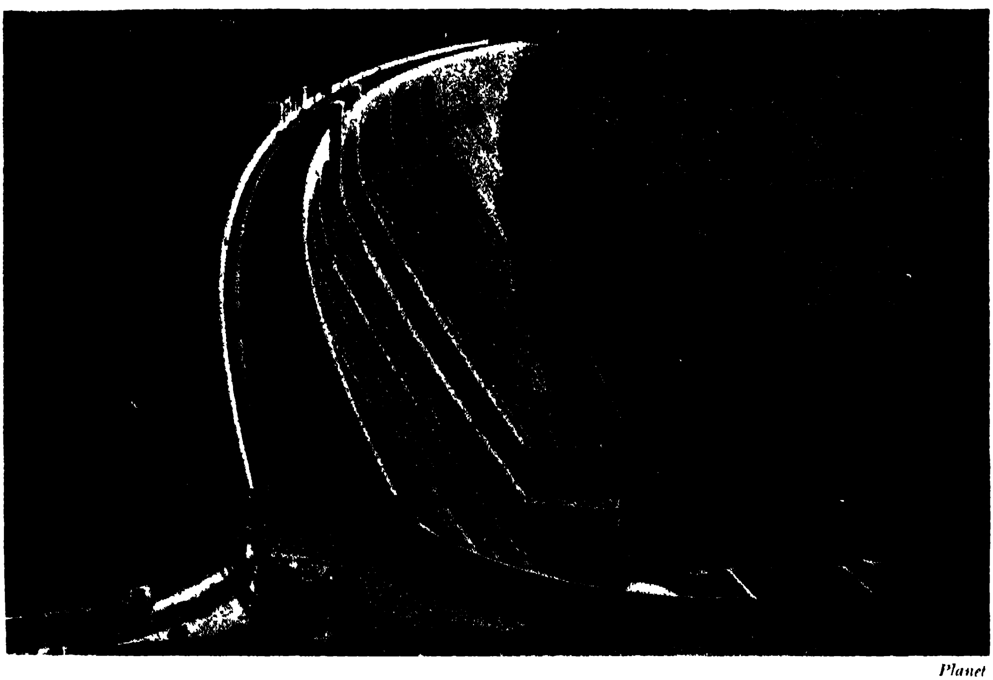
Nearly half-a-mile long, 300 feet high above its base, and 200 feet thick at the bottom, it holds back 32 thousand million gallons of water.

Even this enormous quantity did not prove enough for the ever-increasing demands of the city and a still bigger scheme was carried through. An artificial lake, 12 miles long and one mile wide, was created 100 miles to the north of New York. This lake holds four times as much water as the Croton reservoir. The Catskill aqueduct which leads the water to the city from this mighty reservoir is some 17 feet high and over 14 feet wide for a great part of the distance. It passes right under Croton Lake and later under the East River to Staten Island after traversing some 125 miles.

Australia's Long Aqueduct

For one of the longest aqueducts yet constructed we must go to Western Australia. In 1892 gold was discovered at Coolgardie in an almost waterless desert, many miles west of Perth, the capital. People flocked to Coolgardie and in a short time the shortage of water became acute. This lack of water, and the impurity of the small quantity that was obtainable, led to disease, and this became a major problem. In addition, the railway to the goldfield could not be worked owing to this same difficulty over the water supply.

The Government had to take the matter in hand. A big reservoir was formed near the coast by damming the Helena River and a 350 mile line of steel pipe, 30 inches in diameter, was laid from the reservoir to the goldfield. As the reservoir was much nearer sea-level than the goldfield, eight pumping stations had to be built to pass the water along in stages.



Planet

CLAERWEN DAM, HIGHEST IN THE BRITISH ISLES

Birmingham is the second largest city in Britain and the centre of a great manufacturing area. A large and constant supply of good water is essential for health and industry, and in October, 1952 the Claerwen Dam was opened by H.M. Queen Elizabeth II. The dam is 184 ft. high and a roadway runs along its 1,100-ft top. The opening of this dam marked the completion of a great scheme inaugurated in 1902 by King Edward VII

WITH THE FIRE FIGHTERS

Mirror Features

WHEN THE FIRE BRIGADES FACE HEAVY ODDS

Fire under control is one of our most useful servants, but in its destructive forms it is still one of man's most formidable enemies. Properly organised fire-fighting services were first undertaken in this country by insurance companies but they have long been a public service. Our picture shows something of the task that confronted the brigades summoned to an outbreak at a great rubber dump near London.

FIRE is one of the greatest of the natural forces which has helped man in the upward climb from his earliest savage stage, but it still remains one of his greatest enemies when beyond his control.

The discovery of how to make fire at will and use it for his own purposes was the first big step forward made by primitive man. Yet in recent times fire has destroyed great cities and takes its toll of life and property every year in all countries throughout the world. Man is still faced, as in his earliest days, with the problem and peril of fire in its destructive aspect.

Even to-day, despite the precautions taken to avoid risk of an outbreak of fire, the loss caused in Great Britain amounts to about £12,000,000 each year. During the war years it was of course very considerably more, and never before was the importance of efficient fighting services against this peril made so clear. The lessons learned during those years when this country lived through its ordeal by fire have not been forgotten. To-day our fire-fighting services are highly-trained and splendidly-equipped forces, ready for instant action when the call comes

Methods of fighting outbreaks of fire have existed almost ever since civilisation began. There is evidence that the Egyptians had fire brigades in 2,000 B.C. Hero of Alexandria, about whom we read in Volume VII, described what he called a " siphon " which was used to put out fires in the year 150 B.C. The Romans had a well-organised fire brigade service ready to go into action in any part of their city when outbreaks occurred about the year 40 B.C. Hose pipes for conveying water to help in putting out fires were in use quite early in the Christian era.

In England nothing very much in the way of organised fire-fighting appears to have been undertaken until the early insurance companies began to form fire brigades of their own to protect any property they had insured. This was in the eighteenth century, and an Act of Parliament was passed in 1744 which ordered the church-wardens of all parishes in London to keep a proper engine to deal with any fires that broke out in their own districts.

When Danger was Foreseen

The insurance companies still led the way, however, and in 1833 they combined to form the London Fire Engine Establishment. Their first commander, James Braidwood, was himself killed while fighting a fire near London Bridge in 1861.

Five years later the fire brigades in London became the responsibility of the Metropolitan Board of Works, which was replaced in 1888 by the London County Council. In other parts of the country fire brigades were organised by the local councils and in all the important cities and towns a fairly efficient fire-fighting service was gradually developed.

When the Second World War broke out in 1939 it was realised that the risks of fire had been enormously increased. The authorities had foreseen the danger in advance and an Auxiliary Fire Service had been formed to assist the regular brigades. Large numbers of trailer pumps, hose and other equipment had been distributed to fire brigades throughout the country by the Government.

There were some 1450 brigades in England and 200 in Scotland, and in 1941 these brigades were united to form the National Fire Service.

The number of firemen was very considerably increased and, as in the fighting forces, women were brought in and did great work in control rooms, as drivers, wireless operators, motor-cyclists, cooks, and in running mobile kitchens and canteens to help in sustaining the firemen during their arduous tasks. In addition, of course, many clerical posts in the Fire Service were filled by women.

Some part of the story of the magnificent work these men and women of the National Fire Service and the Women's Auxiliary Fire Service did during those strenuous years is told in "Their Finest Hour" in Volume II. In one period of twenty-two days and nights in London the fire-fighters were in action at nearly 10,000 fires, and in other great cities many similar stories of courage and endurance can be told.

The National Fire Service was, however, formed only as an emergency measure and with the end of the war there came a desire for the Brigades to return to some measure of their old independence. Local patriotism counts for a good deal and many of our Fire Brigades have their proud records and traditions of service in the same way that many of the famous regiments in the Army cherish their traditions of the past. The Fire Services Act of 1947 provides that for the future the responsibility for fire-fighting will be with the County Councils and certain other authorities in England and Wales; in Scotland with the Councils of Counties and the large Burghs.

Training of firemen in the methods used to combat outbreaks remains similar throughout the country. Many invaluable lessons were learned during the testing years of 1939-45. In London the would-be fireman has 8-9 weeks intensive training at the Training Headquarters in Southwark Bridge Road.

The prospective fire-fighter must be not less than 21 or more than 31 years of age and preferably under 25. He has to pass various tests as well as a written examination before being accepted for training. That these tests are not very easy can be judged

WITH THE FIREMEN IN TRAINING

Fox Photos.

Training to be an efficient fireman is strenuous work and only the strongest and most resourceful men can take up this calling. Above we are shown a team at practice, the tower having been built specially for this purpose. From different floors in the building firemen are attacking a fire with their hoses and we see, on the left exactly how a fire fighter operates from the top of a telescopic escape ladder.

from the fact that on an average only a hundred men out of every thousand are finally passed—and the majority of applicants to-day are those who have served in one of the branches of the fighting services

There used to be a preference for ex-seamen because in the old days the sailor was accustomed to climbing aloft and did not worry about being perched high above deck while he got on with a strenuous job That point scarcely counts so much in these days when sailing-ships are few and the sailor who has climbed the rigging to trim sail is a rarity Even so a man who might feel a trifle nervous when handling a hose at the top of a 90-feet turntable ladder, with flames in front of him and smoke swirling around him, would be happier in some less strenuous service than fire-fighting

For the man in training it is a strenuous day from 8 30 a m to 6 p m

A COOL HEAD FOR HOT WORK

Often where there are towering buildings in narrow streets our fire fighters have to work from the tops of tall ladders as here shown

during these eight to nine weeks before he takes his final tests These tests are not only practical and technical, but there are written papers and an oral examination as well before he is finally passed as qualified for the Service

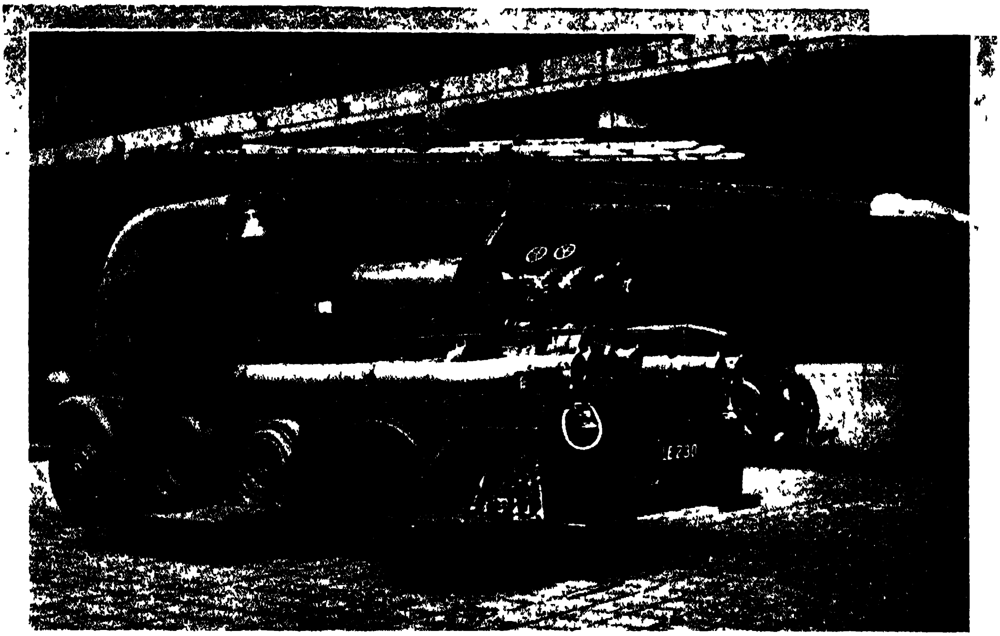
Teams in Training

Take a brief look at the Training Headquarters on any normal working day In one yard a squad of men are practising with extensible ladders of which there are various types On this occasion the ladder is touching the wall of the building by an open window

A fireman goes up, clambers through the window, and in a few moments is climbing back on to the escape again But now he has one of his fellow recruits across his shoulders and brings him down the escape to lay him gently on the ground True, he does not rest there very long but practice in careful handling of rescued persons is as important as practice in seeing that every safety device on the escape ladder is in its proper position

Later the team take turns at this rescue act from the roof Every man has his full share of practice in carrying down a human burden – and in playing the part of the burden as well ! It is not merely practice in rescuing and in learning self-confidence, but in knowing just what it feels like to be rescued In the early stages of their training most men prefer to be the carriers rather than the carried !

Other ladder practice in another part of the training-school is with the type of ladder which is so made that it can be readily attached to a top-storey window These ladders are fitted with a saw-like steel bar, with a hook at the end, to enable them to take a firm hold on the window-sill First, the fireman climbs to the first storey on one ladder then a similar ladder is handed to him by a comrade and this is fixed to the next storey window A quick test



A SELF-PROPELLED PUMP WITH LADDERS

The engine seen above is one of our latest fire-fighting appliances, speedy, reliable and equipped with every device science can create for the work entailed Contrast this with the horsed engines and escapes which once dashed through London's streets To-day there is one unit, and in many cases the self-propelled pumps carry their own escapes.

assures the fireman that the ladder has gripped on properly.

Up the ladder the fireman goes and the performance is repeated until the top storey is reached when the process is reversed. Watching a fairly advanced class on this particular exercise gives the impression that it is comparatively easy to young, fit men and just a matter of routine: fixing, testing, climbing, clambering from ladder through the window, then drawing up the ladder to repeat the process again does not look a very difficult task.

But watch a fairly new class of recruits practising the early stages of this same very necessary exercise and the onlooker has a wonderful lesson on the difference which experience and practice make.

In a lecture-room another class is being shown by an instructor the simple equipment employed to put the overhead live wires used for trolley-buses and trams out of action when they are likely to be dangerous during rescue work. There is a good deal to be learnt about equipment and its proper use. A fireman's job is one in which the motto "Be Prepared for any Emergency" is highly necessary.

Ready for Accidents

What is a fireman doing when he is not actually fighting fires? Looking after the apparatus and equipment? That is one task, of course, since everything must be instantly ready when the call comes. But fires are not the only calamities to which the firemen are called. A train smash or an aeroplane crash are just as urgent calls to action as a fire. When floods occur the most desperately-needed help is that given by the firemen with their pumps, in addition to any rescue work that may be necessary.

Then there are minor accidents such

as lifts sticking half-way between two floors, imprisoning the unfortunate passengers. The firemen know just how to handle this problem. Or a small boy finds it comparatively easy to push his head between iron railings so that he can get a better view of what is going on down below. It is only when he tries to bring his head back again that panic comes. His head obstinately refuses to come back though it went through the railings easily enough.

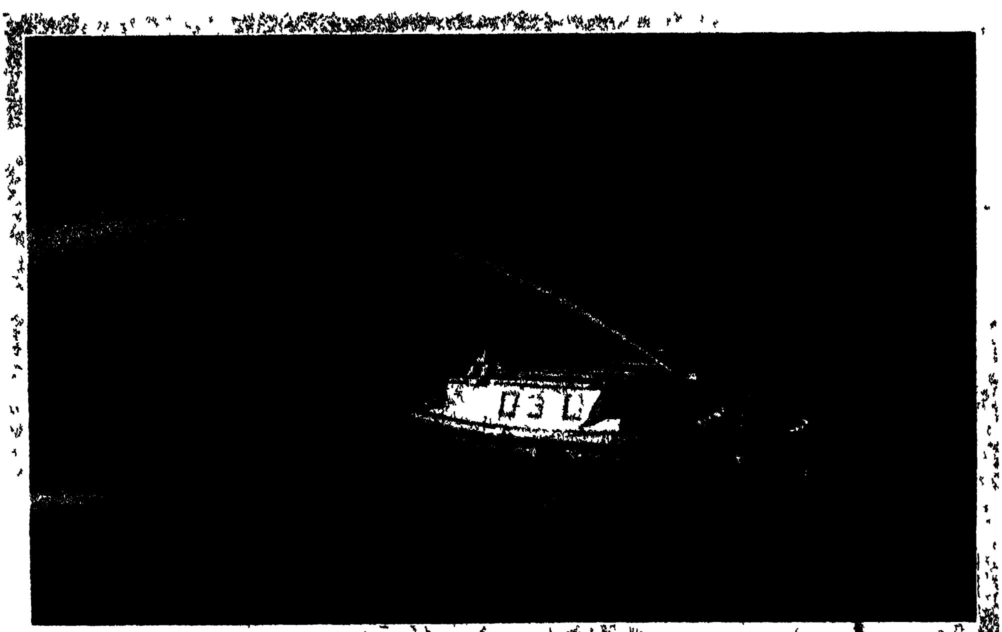
Caring for Animals

It is generally the fireman's job in the end Usually special expanders are used which force the railings far enough apart for the small imprisoned head to be withdrawn and accompany its owner to the home to which his legs have been so anxious to carry him ever since the tragedy happened.

Animals, too, provide work for the firemen. The venturesome kitten climbs a tree, and, like the small boy, gets stuck in some impossible position from which it cannot escape by its own efforts. It can and does proclaim its trouble to all the world within hearing. Usually it is the fireman with his ladder who is called to the scene and carries out the rescue work quickly and efficiently.

An affectionate regard for animals is among the traditions of the Fire Service. There is a memorial stone at Southwark Bridge Road recording the virtues of Bill, the station cat for eighteen years, who was evidently a prince among cats, and yet, like all other cats, loved warmth—and a good fire!

Animal stories are numerous. There was a horse that went up the steps to a house, through the front door and the hall and up the narrow stairway without causing any traffic jam. It was only when it was in one of the



THE FLOATING FIRE ENGINE

For use against ships burning in dock or mid-stream and for fighting fires in docks and warehouses specially-equipped fire-floats are used. In this photograph one of these fire-floats is in action, her side illuminated by a blaze on the river bank. Fire floats can often draw much nearer to conflagrations than could a vehicle ashore and they are never short of water because this element is all around them.

HOW THE FIREMEN LEARN AND WORK

Fox Photos

In this picture is a scale model of a warehouse and offices Smoke is pumped into the model to give realism and the firemen are then instructed in their work

Fox Photos

The photograph above, taken during a display given by London Firemen, demonstrates how a person is rescued from a burning building merely by the use of lines

Central Press.

For work in some classes of fire, when the smoke is very dense or charged with gas or acid, it is necessary for firemen to wear breathing apparatus

Central Press

In this picture the rescuer is wearing a self-contained oxygen breathing apparatus and carrying his human burden by the method known as the "Fireman's Lift."

upstairs rooms that the trouble really began. Getting into the room had been simple; getting back into the road again was a vastly different proposition. It was another job for the firemen and they did it all right.

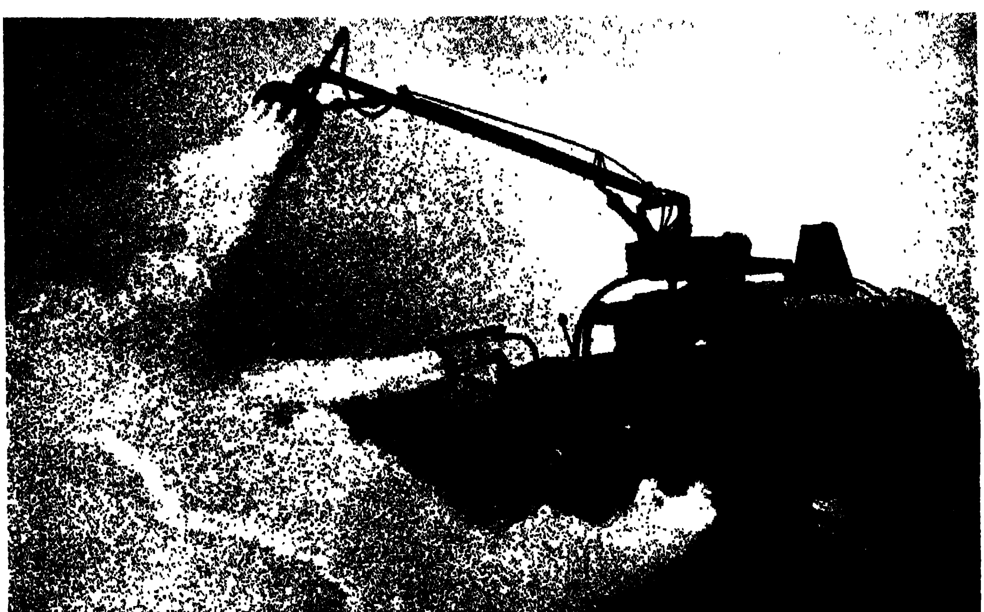
Traditions of a Great Service

But fighting fires and rescuing those in peril remains the great task. Over the entrance to one of the buildings at the Training School is the advice given many years ago by Sir Eyre Massey Shaw, chief of the London Fire Service from 1861 to 1891. Every recruit to the Service is shown this notice written out in large letters:

"A fireman to be successful must enter buildings; he must get in below, above, on every side, through panels of doors, through windows, through loop holes, through skylights, through holes cut by himself in the gates, the walls, the roof; he must know how to reach the attic from the basement by ladders placed on half-burned stairs, and the basement from the attic by rope made fast on a chimney. His whole success depends on his getting in and remaining there and he must always carry his appliances with him as without them he is of no use."

For service in our great ports special equipment is often necessary, and fire-floats will take the place of the road-engines normally used. Again, a different technique is required at big airports, where the danger of an aeroplane making a crash-landing and bursting into flames is always a possibility.

There have been changes in equipment and in methods, but the spirit, traditions, and the discipline of this great fire-fighting service remain as they were when this advice was first penned nearly ninety years ago. Among the many and varied services which have been built up in this country for the common good, our fire-fighters hold a highly important place.

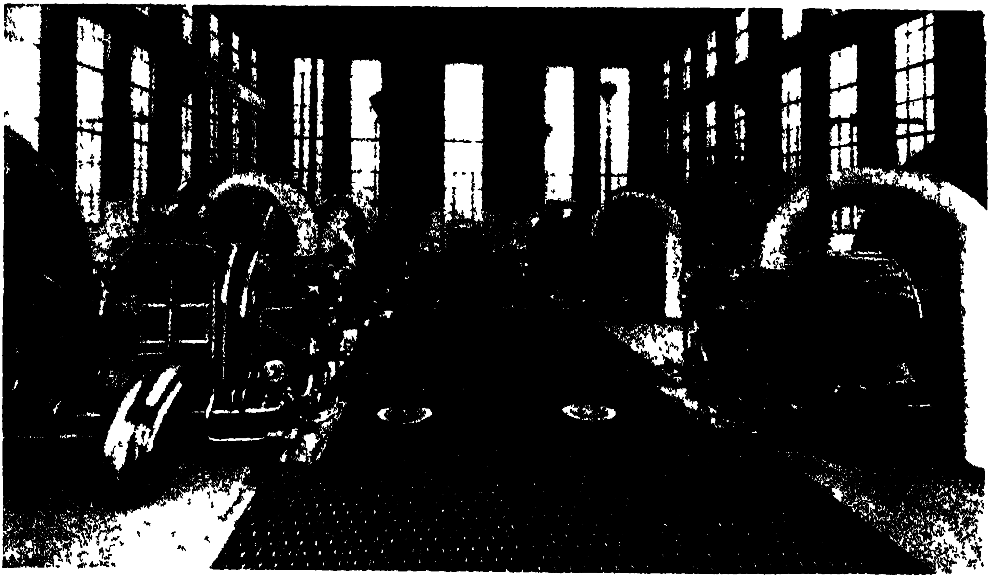


Mirrorpic.

FOR FIGHTING FIRES AT OUR AIRPORTS

The most modern and most efficient fire engine in the world is this new type which has recently been installed at London Airport. It is seen here in action as it sends forth streams of CO_2 gas. The top fountain will go round and round in a circle when necessary. The engine is driven right into the centre of any aircraft fire and the clouds of white gas immediately extinguish the flames.

HOW WE GET OUR GAS



North Thames Gas Board

DRIVING THE GAS HOME

This is a view of the plant used for pumping gas into the great mains which interconnect gas making and gas distributing stations in London, and enable any one to draw supplies from elsewhere. The pressure in these mains from the "booster house" is considerably higher than that in the ordinary distributing mains of a district

IN the year 1810 there was formed in London a company called the Gas Light and Coke Company, to supply gas and coke to the public. The idea of doing such a thing was novel, and many people regarded it as quite impracticable. The company, however, was granted a royal charter in 1812.

From East to West

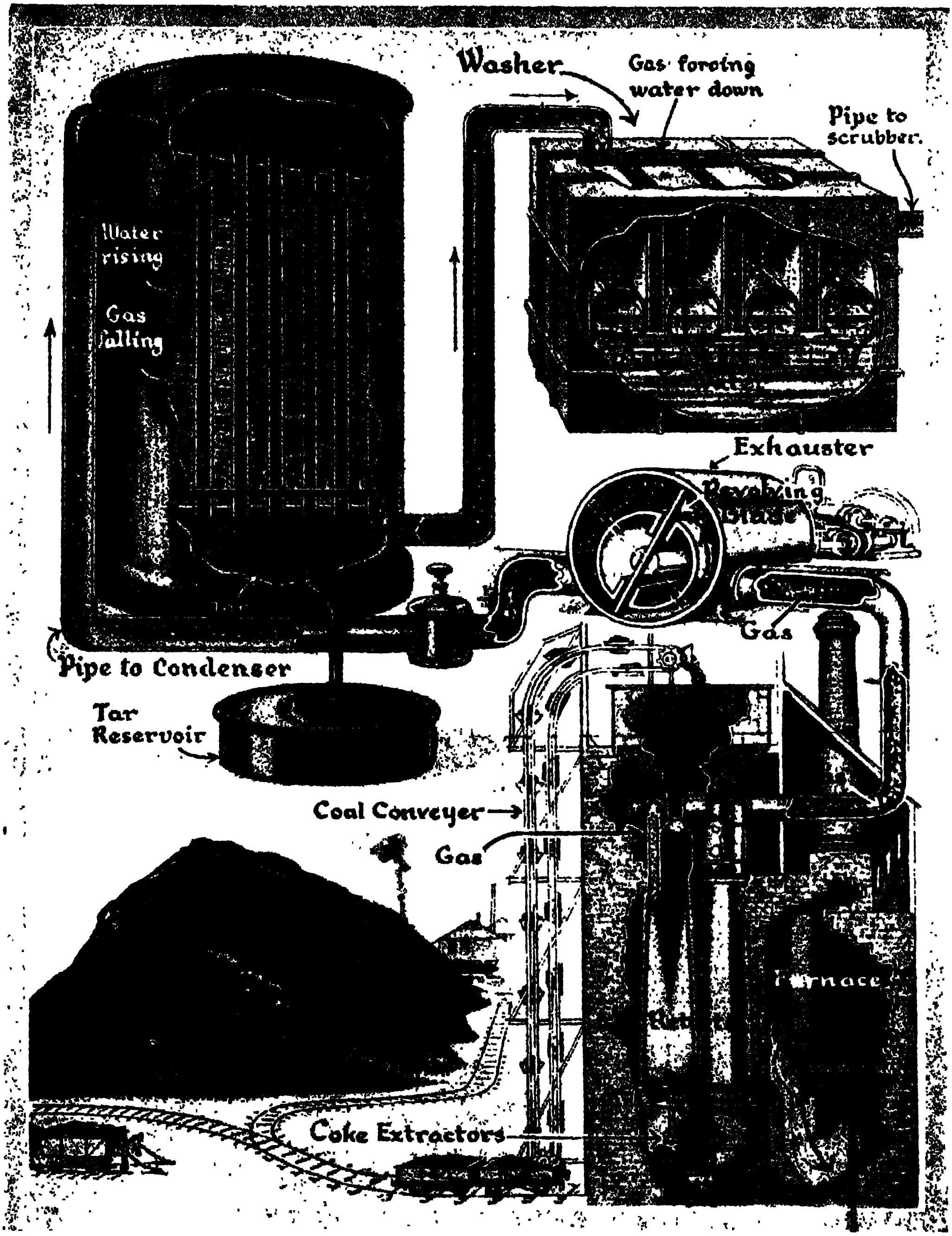
In its early days it had many difficulties to fight against, and experience in gas-making was bought at heavy cost, which made the shareholders very downhearted at times. But after it had got over what we may call its teething troubles, the Gas Light and Coke Company began to grow lustily, and gradually new gas companies came into existence throughout the country.

Then on May 1st, 1949, the 1,037 undertakings in the British gas industry, some of which were independent companies while others were owned by local authorities, were all taken over by the Government and became State-owned. The nationalised industry is now controlled by the Gas Council and by twelve area Gas Boards. The total number of consumers served by the industry in 1951 was 11,981,107, of whom 11,230,607 were domestic consumers.

Altogether the industry supplies some 2,460 million therms (equal roughly to 500,000 million cubic feet) of gas to its consumers in a year, and about 143,000 workers are employed. Nearly 26½ million tons of coal are carbonised in a year.

Gas is not by any means the only product of the gasworks. The coke which is left behind in the retorts is used in millions of homes for water heating and as a smokeless fuel for fires. About 11¾ million tons of coke are sold every year, and the demand for coke still exceeds the supply. Tar is another

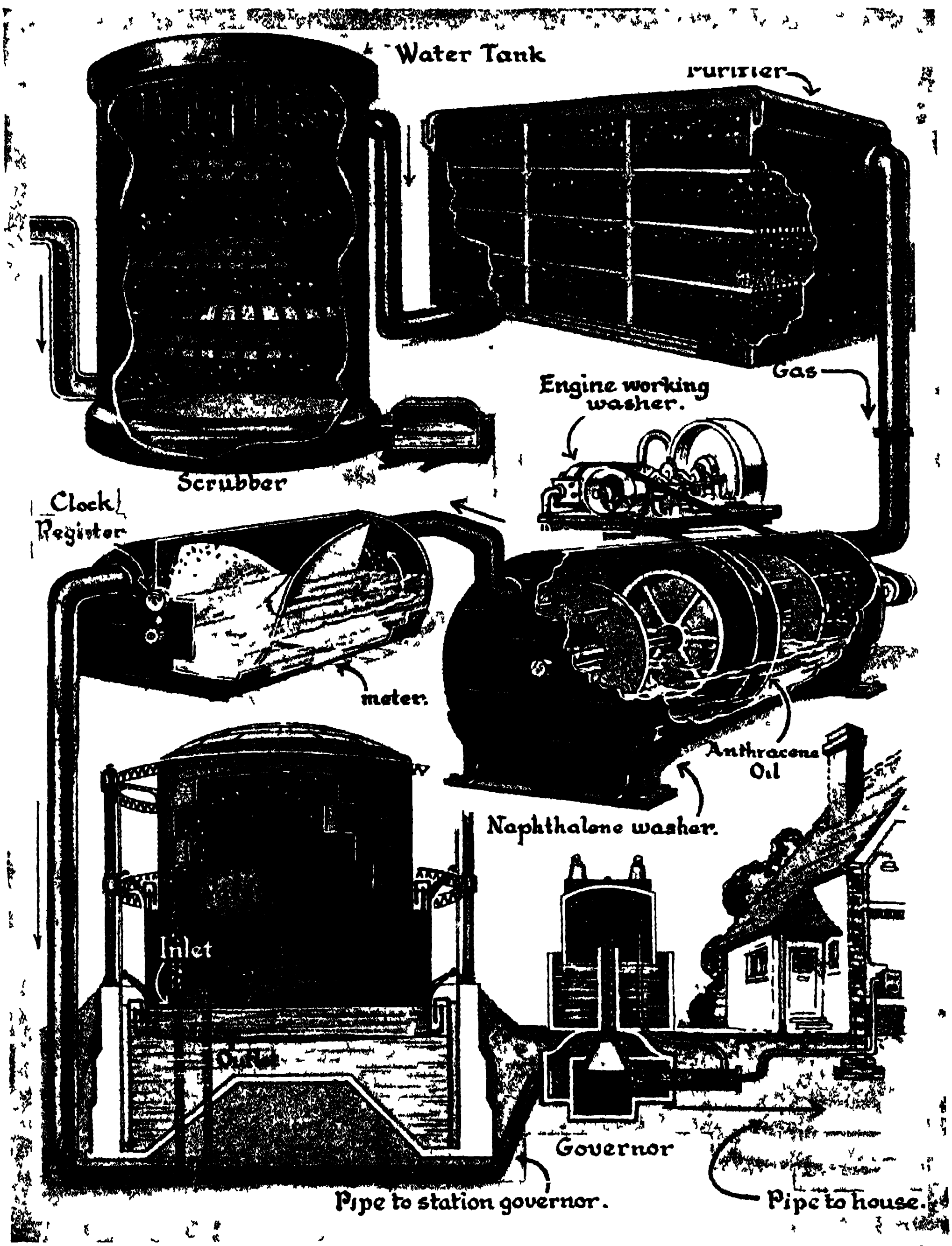
HOW COAL GAS TRAVELS—



Specially drawn for this work.

The life-history of coal gas begins in the retorts—the latest form of vertical retort is here shown—where the gas is separated by heat from the solid coke of the coal. The gas is pulled out of the retorts by a blower, which drives it forward through the many parts of the plant which free it of various impurities. These, if allowed to remain in it, would cause troubles of different kinds, whereas when extracted they can be turned to useful account. In the condenser the hot gas is chilled and releases the tar, which falls to the bottom and is drawn off into a reservoir.

FROM RETORT TO CONSUMER



Specially drawn for this work

The gas next passes through water in a "washer" and rises among falling water in a "scrubber" to be deprived of ammonia gas, which the water absorbs greedily. In the "purifier," next encountered, the gas moves over trays of iron oxide. The oxide robs it of sulphuretted hydrogen, a very evil-smelling gas. Further apparatus extracts anthracene oil, naphthalene, and benzol, the last of which is used as a motor-car fuel. Between the gasholder and the distributing mains is a governor which automatically regulates the pressure in the mains.

valuable by-product of the gas works, and nearly 1½ million tons are supplied each year. Over 2,000 different chemicals can be made from tar alone. Other products of the gas works are dealt with elsewhere in this volume, but it is necessary to stress this aspect of gas manufacture since so many industries rely upon the by-products obtained when coal is carbonised.

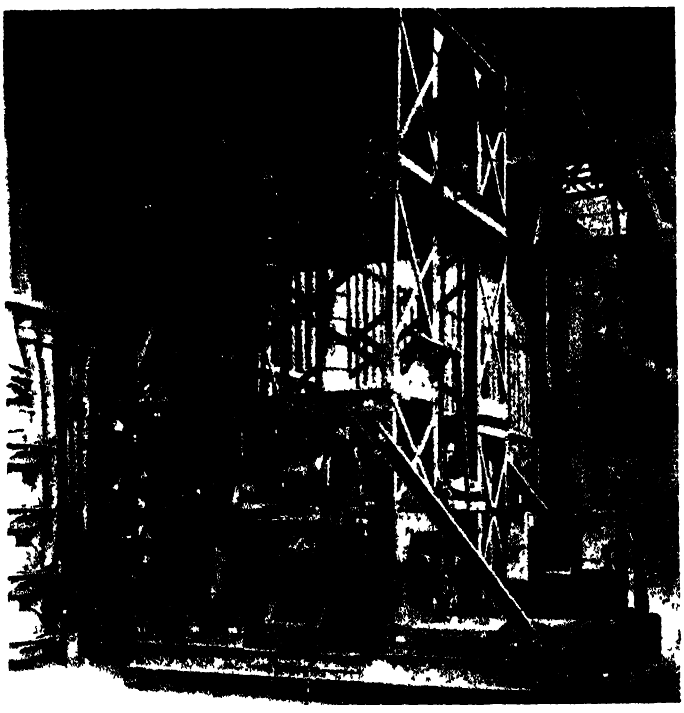
A good deal of research work has been carried out to ensure that the gas supplied to the domestic consumer is not wasted. Modern gas appliances are designed to work most efficiently at a certain pressure of gas and for a certain quality. Cooking uses more gas than anything else, and the demand at certain hours of the day is particularly heavy. Now that the industry is nationalised it is possible to increase the already considerable amount of interconnection between the works in different areas so that there will be a steady supply of gas to all users, no matter how heavy the demand may be.

What Gas Means to Us

The replacement of gas by electricity for lighting may give rise to the belief that gas is of less importance than formerly. Such a belief would be a mistaken one, however, for the use of gas has increased almost as much during the last five years as during the preceding twenty years.

The fact is that people are depending more and more on gas for cooking and heating, and less on raw coal, because of the greater cleanliness and convenience of the first. Its use for lighting purposes with which it first began has now become considerably less, but in other directions gas consumption is increasing steadily and this is especially true so far as its use in industry is concerned.

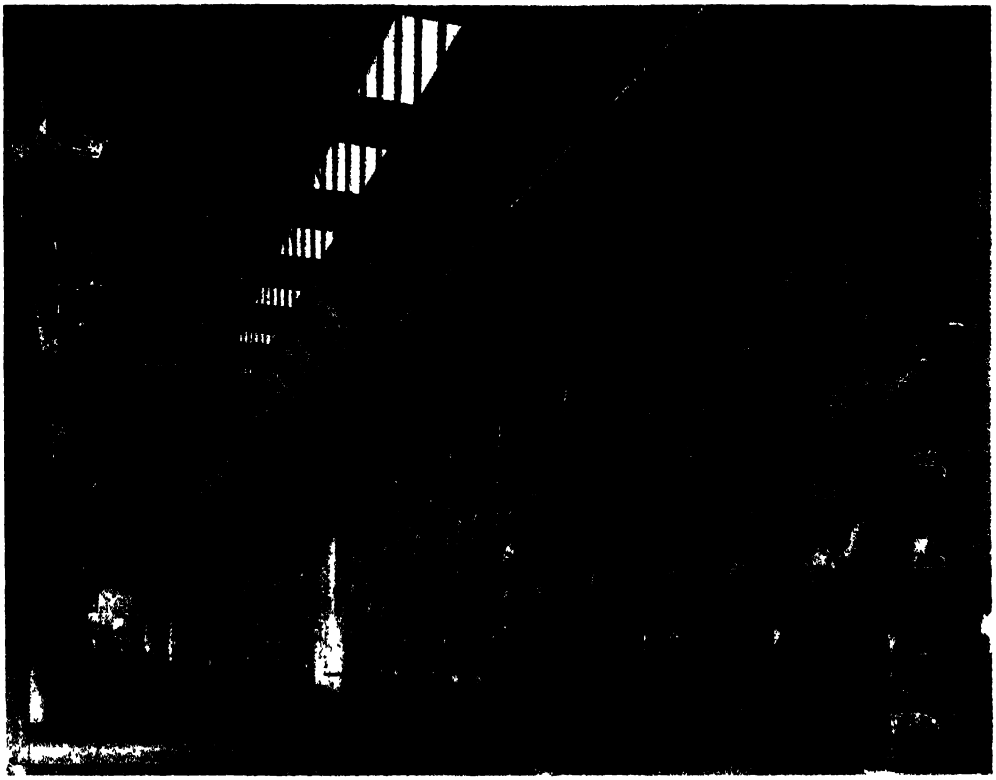
Many houses are supplied with gas through slot meters. The consumer drops in a shilling, and when the amount of gas to the value of the coin has passed through the meter the supply stops, and another coin must be contributed. But domestic heating is only one of many applications of gas, for coal-gas is used as a fuel in over 3,000 trades, and on the average for more than seven processes in each. The gas industry in this country therefore fulfils a highly important purpose.



North Thames Gas Board

A GIANT STOKER

This great machine, moving on rails behind the rear ends of the retorts in a retort house, performs two duties It thrusts into each retort in turn a rammer, which pushes the exhausted coke out through a front end, and at the same time introduces a fresh charge of coal, supplied from the hopper which brings it at regular intervals



North Thames Gas Board

INSIDE A HORIZONTAL RETORT HOUSE

This picture shows us the cast-iron ends of hundreds of retorts, which extend right through a huge block 20 or more feet thick. In twelve hours or so about 13 cwt. of coal is baked in each retort till it has given up all its gas, which passes out through one of the many upright pipes

A Tour of a Gas-works

Let us pay a visit to one of London's largest gasworks at Fulham. These are now more than 100 years old, and probably the oldest in London. But in spite of their age, they have, so to speak, always kept young in the sense of being up to date. A tour of the 35 acres which they cover serves to dispel any belief we may have entertained that gasworks are uninteresting, even though very necessary, parts of our civilisation.

Our conductor leads us down to a wharf on the northern bank of the Thames, where we find a large sea-going ship, one of the colliers that has brought 1,750 tons of coal direct by water from the Tyne. How it passed under sixteen road and railway bridges seems a bit of a mystery until we learn that its funnel "dips," and that the ship is designed specially for up-river work.

On the wharf are three large cranes, each carrying what is called a grab. This has two great jaws which, when closed together, form a large semicircular bucket. One of them is being lowered into the hold with its jaws spread wide open. It settles on the coal below, and as it is raised bites deeply into it till its jaws meet. Then up it comes with 4 tons of "run of mine" coal, that is, unscreened coal of all sizes, from good-sized lumps to dust. The crane swings it round over a great concrete hopper, and opens it. Back it goes again for another dip. Between them the three

grabs will unload the ship in five hours. Pretty quick work this—and quick work is needed, since the station always demands 1,500 tons of coal a day.

Through the bottom of the hoppers, which hold 2,000 tons, the coal falls on to an endless rubber belt, 30 inches wide, which runs over sets of rollers placed a few feet apart. The rollers give the belt a trough shape, and this prevents the coal spilling.

Carried by Belt

The belt rises on an inclined framework to a height of 20 feet or so above the ground, and passes the coal on to another belt, from which it is transferred to another and another till it reaches a crushing station, where it goes through machinery that breaks up all the large lumps. Thence it is carried by belts to storage hoppers at the top of the retort houses. Before rea hing the breaking station, by the way, it travels over a yard, where any not needed for immediate use can be thrown off on to a great long pile. This pile has a railway track on either side of it for a travelling crane and grab, which transfers coal from it to two other parallel piles, or trims the piles as needed, or picks up coal from the piles and puts it on to the belts again.

The storage piles are a very important feature of the works, for in them can be collected up to 40,000 tons of coal as a reserve. One notices many iron bars and pipes sticking out of the piles. They go right through them, and warm up if the coal becomes hot underneath. Thermometers can be let down inside the pipes to find out what temperature is registered.

Where the Gas is Made

We presently find ourselves in one of the four retort houses in which gas is driven out of the coal by heat. This one has horizontal retorts. Imagine a very large chamber with a block which is 20 feet thick, and as many high, running down the middle of it.

On each side of this mass of brickwork are five tiers of iron doors, shaped like a D turned flat side downwards, forty in a tier—200 in all The doors are the ends of retorts, which are ovens of silica brick built through the thickness of the block. The retorts are grouped in sets of ten—five pairs one above the other.

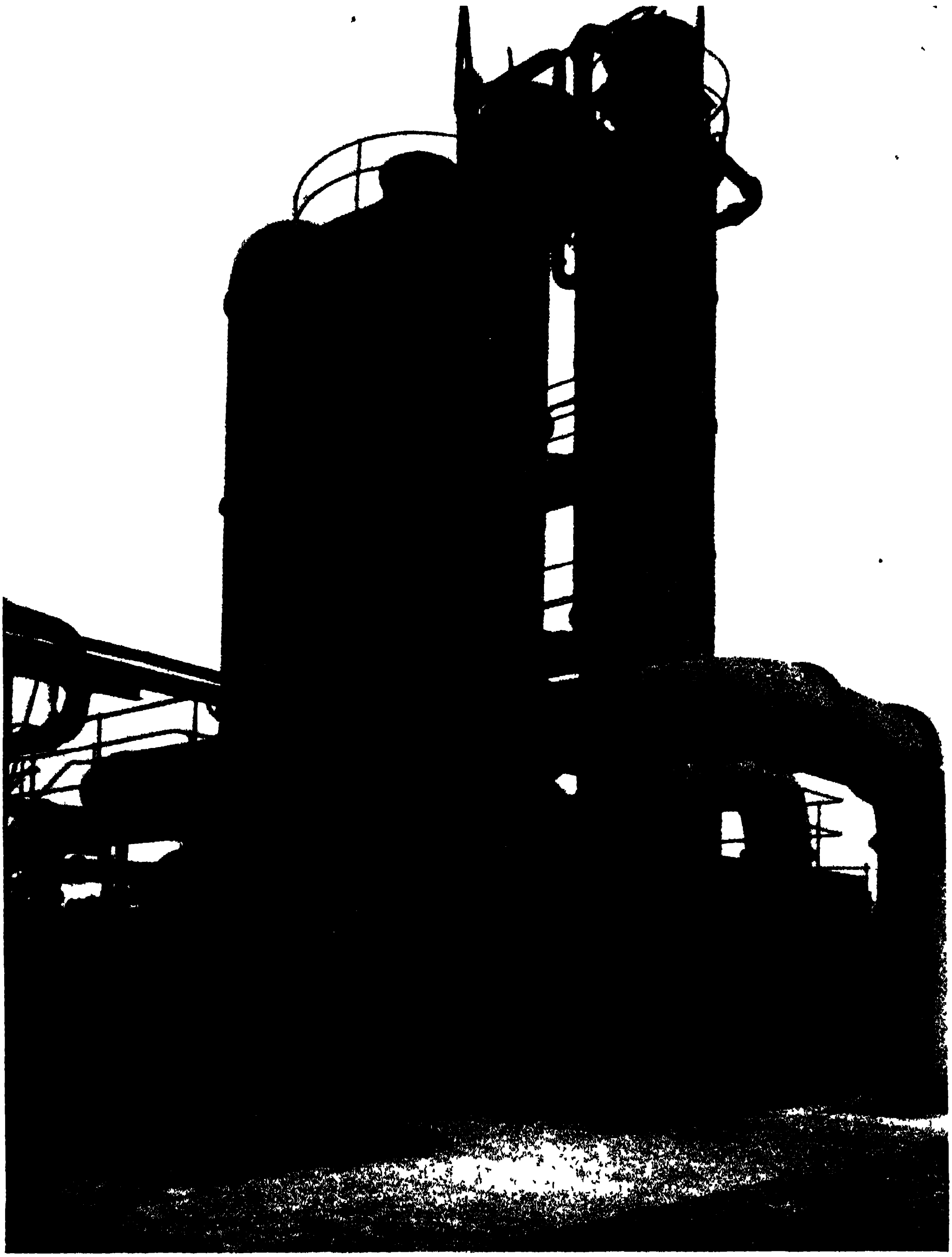
Under each set is a furnace of coke, through which air is drawn to form a combustible gas. This burns as it passes up and down on each side of the retorts, raising them to a temperature thirteen and a half times that of boiling water. After doing their duty in heating the retorts the gases are carried away through huge pipes to boilers, where steam is raised for generating electricity and other purposes. The use of the waste heat in this way means a saving of thousands of tons of fuel every year.

On one side of the wall are rails for a great machine which does the double duty of pushing the coke out of a retort that has been "cooking" its charge for twelve hours, and putting in a fresh charge of 13 hundredweight of coal. A retort door is opened and flames pour out for a moment. Then the machine comes opposite it. Inside the machine is a great eight-sided drum with a jointed rammer lapped round it. The drum revolves, and the rammer is forced into the retort. Meanwhile, its trough-like links receive coal from a bin in the machine fed from overhead hoppers and carry it into the retort. Presently the rammer is withdrawn and wound up again on the drum.

"Drawing" the Retorts

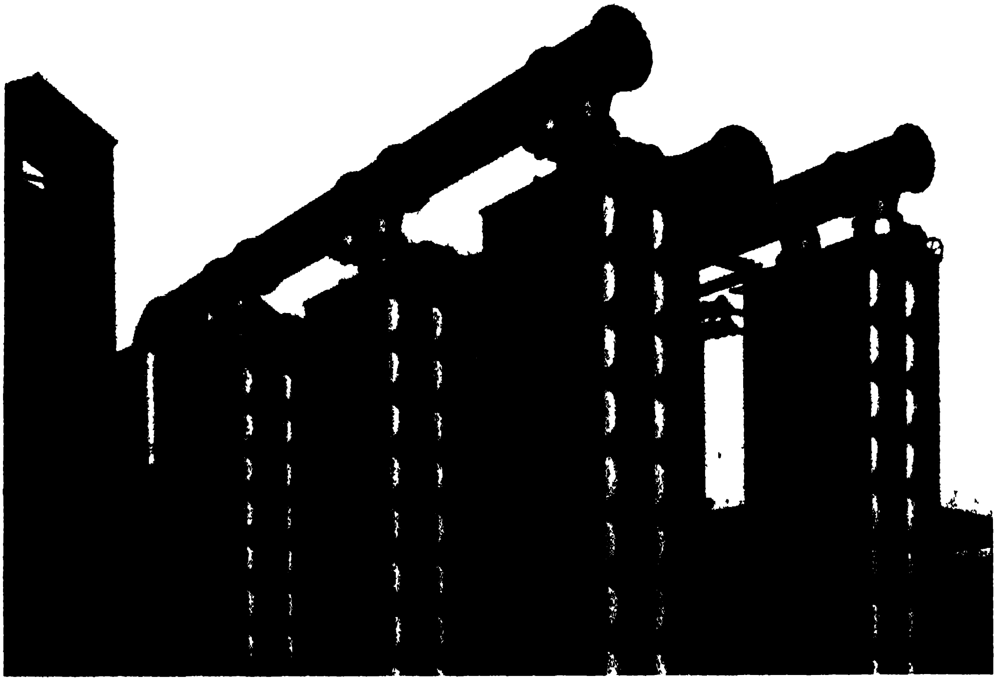
We now go through one of the tunnels in the wall to watch the effect of the operation from the other side when the next retort is "drawn." The heat drives us back as a torrent of red-hot coke issues from an open door and falls

DRYING THE GAS



North Thames Gas Board.

This plant removes most of the moisture from the gas by means of a concentrated solution of calcium which flows down a packed tower. The gas streams upwards through the packing, and the moisture is absorbed by the solution. The diluted liquor is reconcentrated on another part of the works and used again. This photograph was taken at the Southall works of the North Thames Gas Board.



North Thames Gas Board

COOLING THE GAS

The hot gas from the retorts is sent through condensers, which chill it and make it part with most of the tar that it carries. This picture shows a group of condensers, containing many pipes through which cold water circulates. During its passage among the pipes the gas gives up much of its heat to the water

on to a conveyor running at floor level along the front of the wall.

The retorts are drawn in rotation, a " round " being made in twelve hours. So there is a steady supply of gas coming away from year's end to year's end. Before troubling ourselves about what becomes of the gas after it leaves the retorts we inspect another building in which the retorts are upright. The advantage of this kind of retort is that it takes up less floor space and works continuously, coal being fed in at the top at short intervals and drawn off steadily at the bottom. Also, the coke is delivered cold instead of in a red-hot condition.

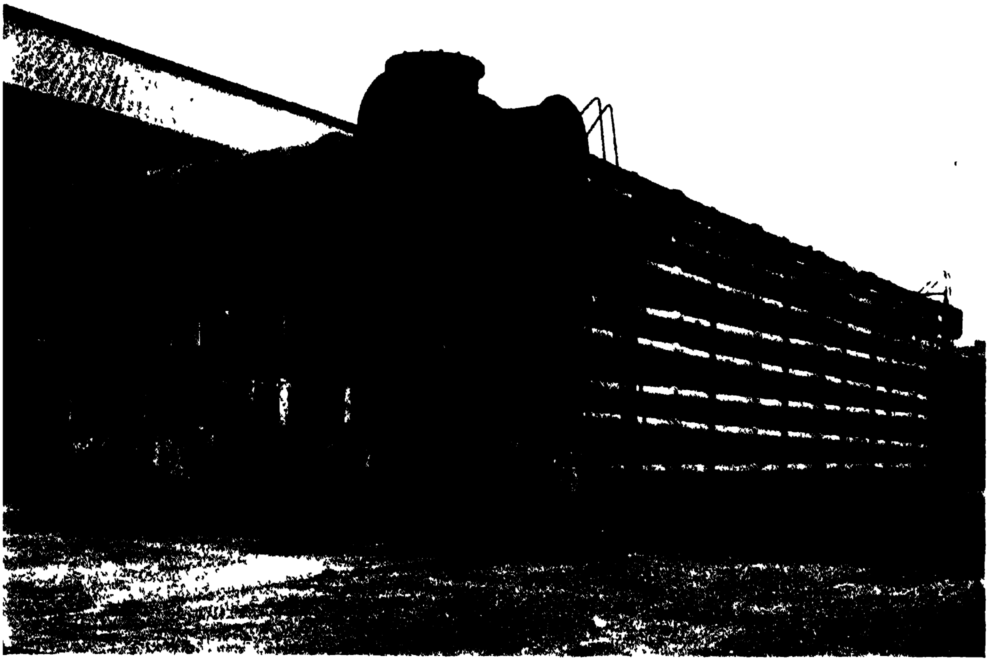
An electric lift takes us to the top of a vertical retort house, from which we get a very fine view of London for many miles round. After admiring this we turn our eyes indoors to a belt conveyor which is feeding a number of hoppers. The bottom of each hopper slopes in all directions towards four outlets, through which coal is drawn off for two retorts below.

On the Charging Floor

Descending a staircase, we find ourselves on the charging floor, below the hoppers. Our feet are now level with the tops of the retorts. By moving a lever, coal is let into a box, from which it can be released into the retort under it without admitting air.

Our guide selects a retort not in use, and lifts a cover. We peer down into a shaft nearly 27 feet deep, and measuring 100 inches by 10 inches at the top. The last two dimensions increase gradually downwards to 104 and 18 inches at the base, in order that the coal may not jam as it is coked during its descent.

There are seventy-two of these re-



North Thames Gas Board.

A LABYRINTH OF PIPES

This is an atmospheric condenser. In this case the gas has to travel from one of the great cross-pipes to the other through the many zig-zags of smaller pipes connecting them, which are cooled outside by the air. You will see that all the pipes of a zig-zag slope gently downwards, so that condensed tar or water shall drain out of them.

torts, and they can deal with about 650 tons of coal, yielding 10,000,000 cubic feet of gas, in twenty-four hours. The retorts are heated by flaming gas rising between them and an outer jacket of brickwork. Then down more stairs to the discharging floor. Here we see hoppers in which the exhausted coke is caught. The movement of a lever empties some of the coke on to a conveyor belt, which takes it out of the retort house.

Gas from Coke, Water and Oil

"I must now show you our water-gas plant," says the obliging guide. So we pass on to another building in which air and steam are blown alternately through glowing coke. The heat separates the hydrogen from the oxygen of the steam, and this oxygen combines with the carbon of the coke.

In this manner a mixture of two combustible gases—hydrogen and carbon monoxide—comes away. This is "enriched," that is, made of greater heating value, by being mixed in a chamber, named a carburetter, with the vapour of a heavy oil got from petroleum. This water-gas plant, we are informed, can convert 70 tons of coke and 5,000 gallons of oil daily into 4,000,000 cubic feet of gas, and is very useful for meeting any sudden demand on the works. Plant of a capacity of 6 million cubic feet per day has been added and the sequence of valve changes formerly carried out by hand is now arranged automatically by a mechanical operator. In the same way the heavy work of clinker removal has been eliminated by continuous extraction through a rotary grate. The gas, it should be added, is mixed in due proportion with the ordinary coal gas before reaching the gasholders.

Cleaning the Gas

The gas would not leave the retorts and travel through pipes of itself, so it is sucked out by engines called exhausters in another part of the works. These draw it through water in a trough called a hydraulic main, in which much of the tar it contains is deposited, and through a condenser which cools it. The condenser is a number of great zig-zags of pipes in the open air. As it flows through these the gas gives up most of the rest of its tar, which trickles down the pipes and is collected.

It is then *pushed* by the exhausters through another condenser, and an apparatus which dissolves the ammonia gas in it in water, and at the next stage it is entirely freed of tar. Then it passes to another plant in which it meets oxide of iron spread on trays, and has the sulphuretted hydrogen taken out.

The liquid containing the ammonia—called ammoniacal liquor—is sent to the Beckton works, where it is used in making sulphate of ammonia, while the oxide of iron, loaded with the sulphur it has picked up, is employed in the manufacture of sulphuric acid.

The now purified gas has a final washing in oil to remove any naphthalene, and goes through meters which can measure 1,650,000 cubic feet an hour between them, to one or other of six great gasholders.

All the coal gas may be passed through lofty towers down which oil is trickled and this dissolves from the gas the benzole and the toluole vapours. This oil at the base of the towers is sent to a still where the benzole, etc., is distilled off.

Like Great Cakes

Gasholders are prominent features of any gas-works. The container, which may be likened in shape to a huge nicely-risen cake, is a framework covered by iron plates ⅜ inch thick. At the bottom it is open, and dips into a water-tight tank rather larger than itself.

The gas enters through a pipe rising in the centre of the tank and by its buoyancy raises the great weight of the container, which, when fully lifted, is still deep enough in the water to prevent the gas escaping under its bottom edge. The container is in some cases kept steady by wheels running on guides on cast-iron columns surrounding the gasholder and braced together; but in others steadiness is given by spiral rails on the outside of the container engaging with guides in the

North Thames Gas Board.

MEASURING THE HEAT UNITS

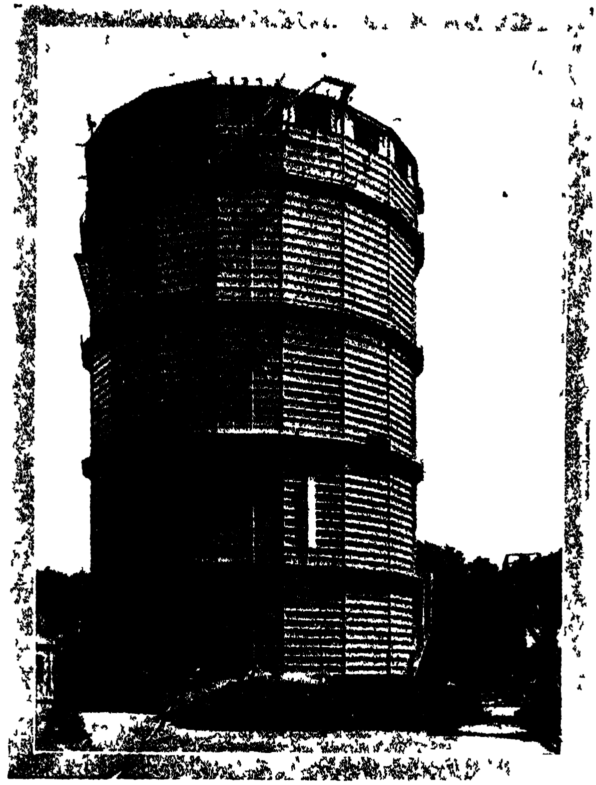
Nowadays gas is sold mainly for heating purposes, and its price depends on its efficiency as a fuel. Consumption is recorded by meters, but the customer pays for the number of "heat units" in the gas consumed. At the works the heating value of the gas supplied is accurately measured by these instruments in the calorimeter room.

tank. In the second instance the container revolves as it rises.

Then, again, very large gasholders are made in two, three, four, five and even six storeys or lifts, telescoping into one another. Only the uppermost one has a top to it. The sides of the others are like a very narrow N in section. Two of the legs form a narrow trough for the lift above, and the third leg dips into the trough of the lift below it. The centre lift rises first, and when it is fully up it begins to raise the next lift, and so on.

The pressure put on the gas by the weight of the gasholder is usually sufficient to drive the gas through the mains supplying the district.

Now that certain additions to the Fulham plant have been completed, it is able to make 35,000,000 or more cubic feet of gas daily, when working at full capacity.



North Thames Gas Board.

A WATERLESS GASHOLDER

This many-sided steel structure is 180 feet high. It is in effect a gigantic cylinder, containing a closely-fitting piston which is forced upwards by gas entering at the bottom.

We must not overlook the coke, which is a very important item in the output of a gas-works, since from every ton of coal used between 14 and 15 hundredweight of coke is produced. Of this, 10 to 11 hundredweight is sold to the public for use in boilers, stoves, forges and open fires. The rest is needed for heating the retorts, making water-gas, raising steam in boilers, and other purposes in the works.

From Benzole and Tar

As already mentioned in the chapter on "What We Owe To Coal" the list of products derived from coal carbonisation as carried out at our gas-works is seemingly endless, and the discoveries made in this direction in recent years are amazing. Continual research and experiment goes on and further advances are certain.

Every ton of coal yields about 3 gallons of benzole. This benzole is treated by the chemist and separated into its constituents: benzene, toluene, xylenes, etc. The separation is done by distillation which simply means boiling and then cooling at different temperatures since each constituent is given off at a different boiling-point.

On page 21 you will find a diagram which shows some of the different substances which are obtained from coal while it is being carbonised to produce gas. From these substances in turn is produced a long list of valuable things we use in everyday life.

While some of the tar, for instance, is used on our roads, some of it is distilled and different kinds of oil are

obtained. From these tar oils the chemists obtain the dyes which have built up another big industry in this country. Antiseptics and disinfectants as well as creosote are also produced.

It is from these oils, too, that the group of drugs known as sulphonamides are derived. Through experiments with these drugs M & B 693 was evolved, and, as a result, many thousands of lives have been saved. Medical authorities calculated that in 1942, one of the first years in which it was used on a reasonably large scale, "the lives saved by the sulphonamides ran well into five figures."

Another fairly recent discovery due to experiments with benzole was D.D.T., the insecticide which has proved such a tremendous help in fighting malaria, bushfever, typhus and other insect-borne diseases in tropical climates as well as in the struggle to conquer the insects which work havoc among our crops. D.D.T. is the most potent single insecticide ever discovered.

Perfumes and Plastics

It is extraordinary to reflect that benzole, the by-product of the gas-works, is to-day an essential of the perfume and cosmetic industry. Until about sixty years ago the perfume-maker depended entirely on substances of vegetable or animal origin for his raw materials. To-day he is supplied by the gas-works with all that he needs and can produce a far greater variety of exotic perfumes than ever before.

Plastics, too, are largely indebted to-day for their great development to the usefulness of phenol, derived from coal tar, and styrene which is chemically produced from benzole. These styrene resins are proving particularly valuable in the electrical industry. From phenol, by other chemical means, nylon is produced and from this new material stockings and parachutes, toothbrushes and aeroplane tyres are now being manufactured.

Modern aviation owes a great deal to benzole. The high octane fuels which are essential for the high speeds now attained are due to cumene, which is derived from phenol. During 1940–45, millions of pounds' worth of benzole products were sent to America for use in the manufacture of high octane aviation fuel. Even in the ordinary motor fuel benzole is used as a blending agent to increase the efficiency of the oil.

Large amounts of sulphur are recovered during the process of purifying the gas, and sulphuric acid is an important raw material of industry. At least 100,000 tons of sulphur are recovered by the gas-works each year, and 95,000 tons are used to make sulphuric acid.

Fertilisers from Coal

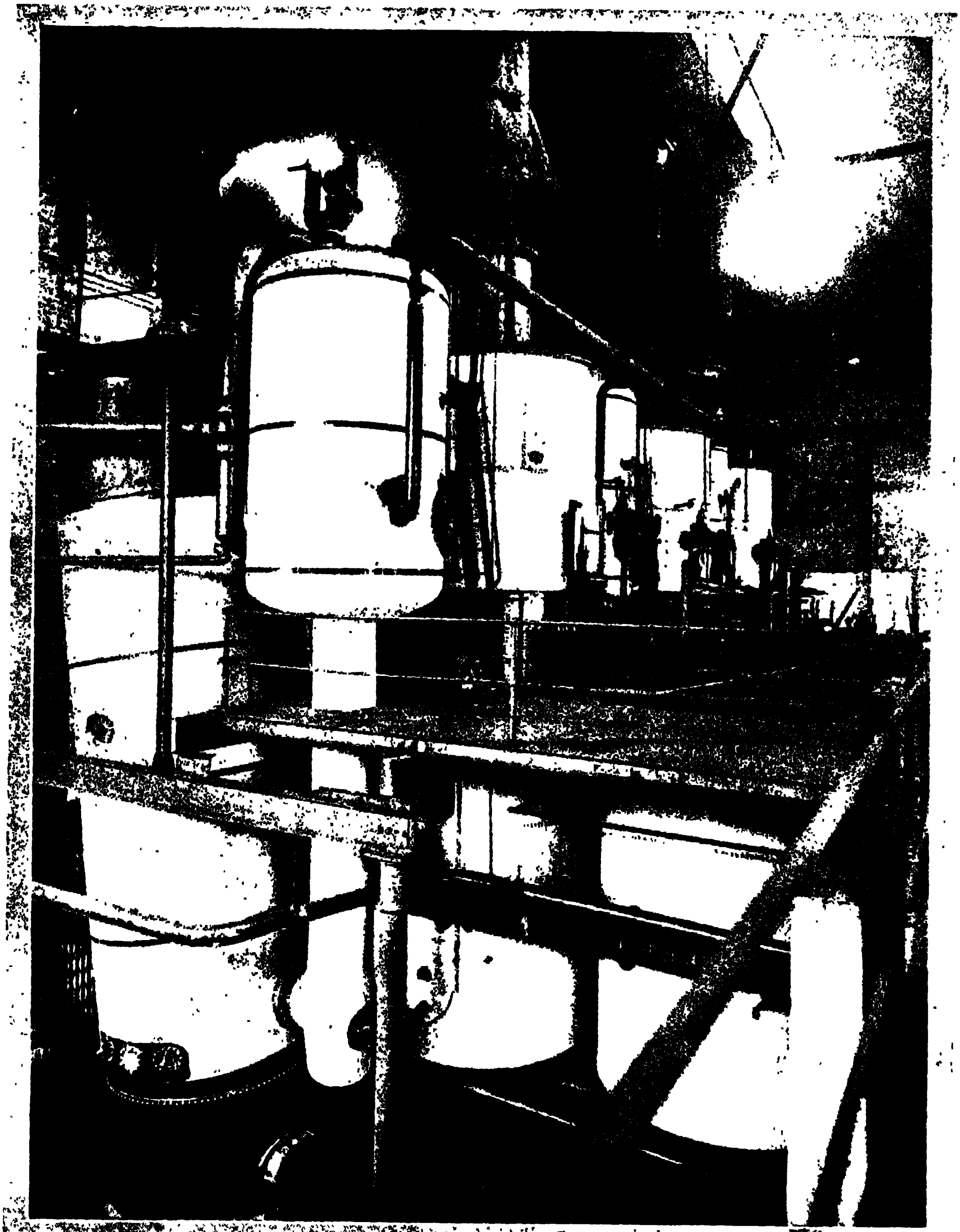
Ammonia, too, is one of the products obtained during the carbonisation of coal to make gas. Farmers and gardeners know sulphate of ammonia in these days as a highly important fertiliser. Its use on land newly ploughed or dug for cultivation is especially useful in ensuring good crops. Some 260,000 tons of sulphate of ammonia are produced annually by the gas industry and in normal times this would be just about sufficient for this country's total requirements.

Beginning of a Big Industry

We have mentioned a few of the products of our age which come to us from coal by way of the gas-works. To go back for a moment to the story of William Murdock and the lamp he made to light him on his way, as told in earlier pages, it will be seen that the history of the gas industry comes into the category of real-life romances. First, coal was burned to produce coke and the gas went off as the smoke still does from our open fires. Then Murdoch discovered the use of gas and may be regarded as the real inventor of gas-lighting.

Instead of coke being the main pro-

A CARBURETTED WATER-GAS PLANT



North Thames Gas Board

Gas suitable for mingling with coal-gas is made in the apparatus seen in this illustration. Waste gases from the furnaces of the retort house are used to raise steam in the boiler on the left. The steam, mixed with air, is blown through glowing coke, and water-gas is formed. This is enriched, that is, given greater heating value, by having added to it, in one of the other chambers, called a carburetter, the vapour of a heavy oil. A water-gas plant is very useful in a gas-works for enlarging output quickly to meet a sudden increase in demand.

duct of coal-burning it became a by-product and the gas itself took first place. A big industry was built and the very name of the Gas Light and Coke Company tells its own story. Then the gas-light was threatened with extinction by the advent of electric light. Gas held its own and even led the way for a brief time, but the new electric light eventually gained the victory so far as the battle of lighting was concerned. By that time, however, other virtues had been discovered in coal and, instead of dying, the gas industry became the pioneer again in the treatment of coal. As a member of the Government put it not so long ago:

"The gas industry has passed through a very complicated history from the time when it produced only light to the present time when it produces fuel, benzole, tar, sulphuric acid, and so forth. Even if it is an old industry it is not very old as we judge things in these days, but I would prefer to regard it as a young industry in the sense that it is just entering on a new sphere of activity. Some of the possibilities that lie before it are only beginning to be seen."

Coal has been a great factor in Britain's prosperity in the past, and to-day every branch of chemical industry looks to coal to supply it with many of its raw materials. Dyestuffs and chemicals, plastics, synthetic rubber, soaps, lubricants, all need the by-products from the carbonisation of coal which produces the gas now becoming increasingly important to industry as a refined fuel capable of exact control.

Gas in Industry

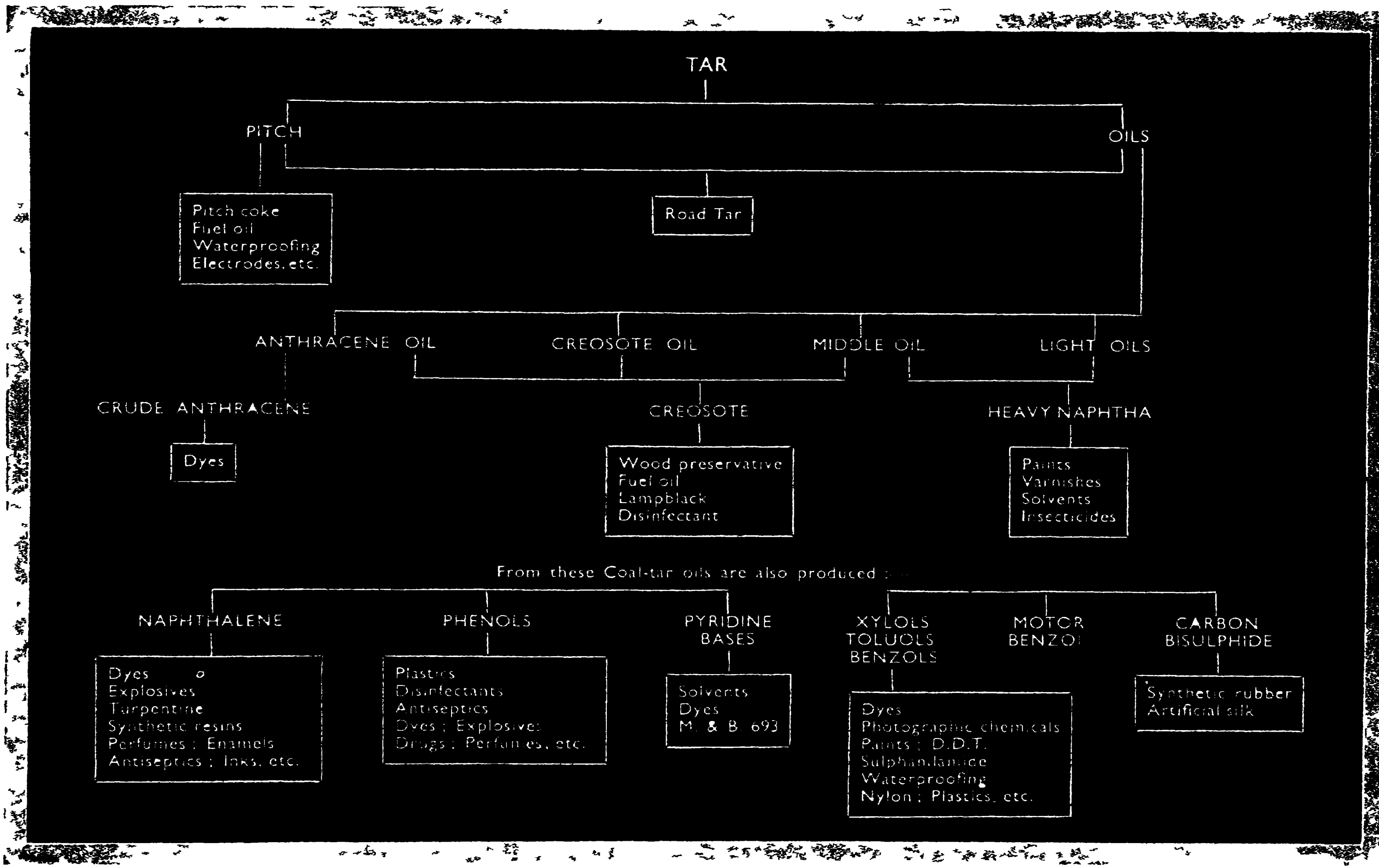
That is the field in which the gas engineers are concentrating their energies to-day: there are gas-burners capable of giving a small pin-point of flame for the jeweller's or glass-maker's art up to those producing large-volume flame or highly-concentrated heat treatment for the steel industry. Gas-fired radiant heat installations are being used for stoving and enamelling. The use of gas-fired kilns and furnaces in such industries as pottery and glass manufacture, as well as in the metal trades, is rapidly increasing. All this means an economy in the use of coal and more exact control of the heating or firing process, while the smoke nuisance will ultimately cease to exist.

Our life as an industrial nation depends upon keeping up supplies of energy and of raw materials for our great manufacturing processes. Owing to our climate we have to use big quantities of fuel to keep our homes and offices, our factories and public buildings, warm and comfortable. But because of the value of all the chemicals in coal, it is obvious we must ensure that its valuable properties are not wasted and coal as a fuel must be used in the most economical way possible.

It will probably mean the gradual disappearance of our old open fires, in which coal is burnt wastefully without any of its valuable by-products being recovered. Gradually, too, gas-fired furnaces are replacing those in which coal is consumed. Only the gas from the coal will be used and other industries will benefit by receiving the raw materials which they require.

At present the gas-works produce 25,000,000 gallons of benzole each year and every gallon is of value in other industries. Nearly 1½ million tons of tar is produced yearly, and tar has been described as the chemist's treasure house.

As the diagram on the previous page will show, the chemist can produce from Coal Tar the essential raw materials for hundreds of different manufactured goods. Coal has become more valuable than gold, and it is through the gas-works and the research



SOME OF THE PRODUCTS OBTAINED FROM COAL-TAR

During the process of gas making by coal-carbonisation at the gas works 10 gallons of Tar are produced from each ton of coal. Our diagram shows some of the products in which the chemist makes use of the oils derived from this coal-tar

chemist that all the treasures coal contains are now being revealed.

Extending the Grid System

Since the gas industry was nationalised, one of the biggest advances has been in the connecting up of supplies by means of a grid system. In the London area, and in certain other industrial districts, there was already a considerable amount of interconnection, enabling supplies from any of a number of works to be sent through the same mains. Now the whole of the area of the North Thames Gas Board has been linked in this way from Southend to Maidenhead, and large schemes are being developed in South Wales and Scotland, in the Lancashire-Cheshire area, the East Midlands and West Yorkshire.

As a result of these grid systems it is possible to cease production at many of the small isolated gas works, which cannot be operated as economically as larger works, and provide gas to areas previously without supplies. The grid system also ensures that exceptional local demands are met without throwing an undue load upon a single works.

This grid system is the latest development in the history of the gas industry, which began when William Murdoch lighted up his house and offices in Redruth, Cornwall, with gas. Ten years later the first public exhibition was held at Boulton & Watts' works, and enquiries began to come in from business men. The first to use gas apparatus made by Murdoch was a Manchester cotton spinner, Mr. George Lee. It was such a success that in 1807 what was probably the largest factory of its kind in the country installed Murdoch's gas-making apparatus.

That was the beginning; to-day, this great industry is of more importance and can contribute more to the common good than at any time in its long history, extending back over a century and a half

LAYING A MAIN

To supply gas to nearly twelve million consumers the gas industry uses 78,138 miles of mains, and new mains, as seen in this picture, are always being laid.

North Thames Gas Board

TESTING THE PRESSURE

The correct pressure of gas, steadily maintained at the same level, is highly important. Here we see a Gas Board official testing the pressure in a 24-inch main.

THE BUSINESS OF THE G.P.O.

BRINGING THE MORNING LETTERS

Every workaday morning, for every house in the land, a postman is available for the delivery of letters. The mail he carries may have come from any corner of the world and been carried by air, sea and land, yet it reaches its destination in the shortest possible time. In its inland business alone our G.P.O. deals with twenty millions of letters and circulars every week day.

LOOKING back through the centuries to the days of Imperial Rome we should find along the main roads that linked the capital with the provinces a series of posts, which might have been of wood, metal or stone.

At each of these stations there was always on duty a team of messengers, one of whom would run with a letter in either direction from his post to the next, when another courier took the missive and carried it on its way. If these men were called postmen, because during their hours of service they were to be found near a post, it would not be surprising, though there is no proof that such was the case.

Much nearer to the times in which we live and in our own country, before the coming of railways, swift dependable horses were kept at certain posts or places along a highway so that people could change steeds and thus travel without having to make a break in the journey whilst their hard-ridden animals were rested. Presently letters came to be dealt with at these posts and the name post office originated. If you journeyed from one point to another as fast as you possibly could you were said to be travelling post, or post haste. Riders entrusted with the mails invariably travelled post and so we have discovered two explanations of how the word post came to be used.

So far as the transport of letters is concerned, the work in remote times was in the hands of private messengers, and then there were people who for brief periods possessed the exclusive right of handling mails, a system that was soon found to be unsatisfactory. Thus it became necessary for the Government to have the sole authority to carry mails, to be granted the monopoly to the exclusion of individuals; and so, in 1657, the General Post Office came into being under the

direction of a postmaster-general. At first, the Royal Mail was invariably carried by mounted post-boys and then arrived the four-horsed mail coaches, the first of them providing a service between Bristol and London, which began in 1784.

After the Mail Coach Days

This was the forerunner of a veritable network of mail coaches, sometimes driven at an average speed of ten miles an hour. Years later the steam locomotive began to run on the so called iron roads and mail coaches had perforce to give pride of place to mail trains.

The first experimental dispatch of mails by trains was made in 1830 between Liverpool and Manchester. Railways still carry the bulk of our letters and parcels but motor transport is also largely used and the air services for overseas mails have grown into a huge business. More recently, the helicopter air service has been used to carry mails between places awkwardly situated for rail or road transport.

G P O

FIRST STAGE IN THE JOURNEY

Having written a letter, you drop it into the nearest pillar box and it starts its journey at the next clearance, as is depicted above.

Since the early days the Post Office has gradually extended its scope of services far beyond the carrying of mails. "Money letters" began in a small way so long ago as 1792 and eventually the Money Order department was established in 1838. It was not until 1881 that the highly popular Postal Order was introduced and rapidly became a big success. Telegrams were at first dealt with by private companies but about 1870 the Post Office took them over, just as eventually the telephone system was taken over, though it was not until 1912 that the Post Office became solely responsible.

So this huge business has steadily expanded through the years. Until 1840 the cost of sending a letter depended on the distance it had to travel. The charge for a letter from London to Edinburgh for instance, was 1s. 3½*d.*, and the amount was collected on delivery. Then, after a struggle, Sir Rowland Hill introduced his great scheme for penny postage throughout the kingdom, and soon afterwards the adhesive stamp as we know it to-day was introduced. Letter-writing increased enormously and in these days the Post Office sells 7,000,000,000 (seven thousand millions) of postage stamps in the course of twelve months and deals in its inland business with 20,000,000 letters and circulars and 650,000 parcels every working day, not counting the many other millions sent to places abroad.

How Your Letter is Handled

To turn from such breath-taking figures, let us imagine you have written a letter, placed it in its addressed envelope, affixed a stamp and dropped it into a convenient pillar box. If you

WHERE NIMBLE FINGERS SORT THE MAIL

The photograph above was taken in a Travelling Post Office van of one of the special trains from London. It shows the staff sorting letters and packages into their proper pigeon-holes. Bags of mail are taken aboard or dropped to the lineside by apparatus whilst the express travels at full speed.

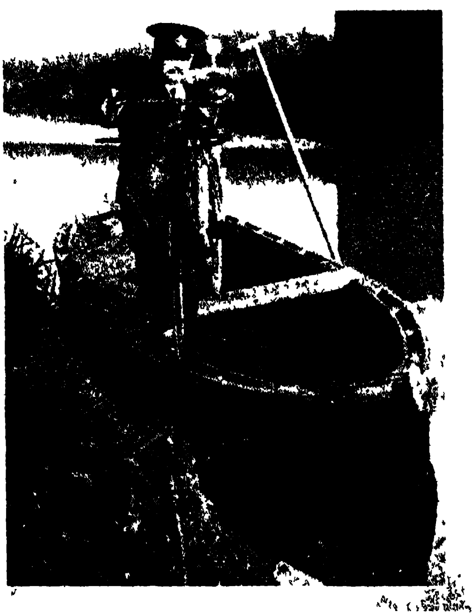
Photos. G.P.O.

That letter you dropped into a pillar box has here reached the nearest sorting office. With other letters, it has been put up in a group, the addresses all facing the same way. The postage stamps have then been cancelled by a wonderful machine, and here we see deft workers sorting into frames each of which has 48 spaces.

have no stamp it is more than likely you can purchase one from an automatic machine attached to the familiar red box. You notice as you leave a printed time-table showing the daily clearances whilst a little tablet in a slot informs you of the number of the next collection.

Presently, the postman who is responsible for the particular route comes along, possibly on foot, perhaps on a bicycle or maybe in a small motor van. With a special key he opens the box and sweeps your letter with all the others there may be into his bag, proceeding on his journey from box to box until eventually he reaches what is called a sorting office, usually in a busy centre and within easy reach of the railway station

What happens to your letter now? First of all, the collecting bags as brought in by postmen are emptied in heaps on long tables so that they can be "faced," which means simply that they are put up into neat, orderly groups with the addresses facing the same way.



Post Office

A POSTMAN OF THE FENS

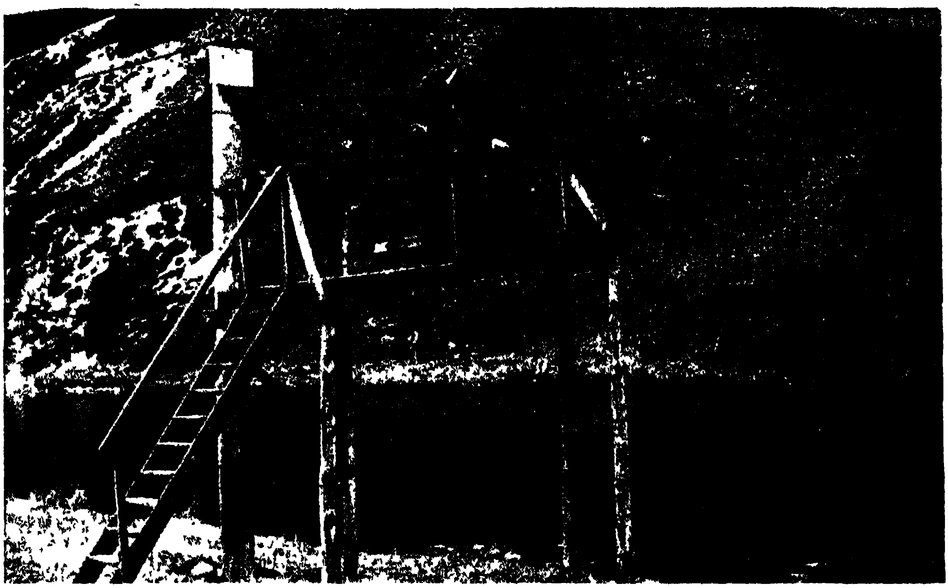
Not all postmen can stick to the highway The one seen above works in the Fenlands and has the help of a boat as well as a bicycle for his round of duty.

This step is taken so that all the envelopes and cards of normal size can be passed through machines which cancel the stamps with indelible postmarks. Some of these machines are capable of dealing with 600 or more items a minute. Envelopes, the stamps for which are placed too low down, too far to the left or on the back cannot be dealt with by the machine and have to be set aside in order that their stamps may be cancelled by hand So, if you do not take the trouble to put the stamp in its proper position you have only yourself to blame should your letter be delayed

Once all the postage stamps have been cancelled the letters or packets must now be sorted according to their destinations. For this purpose, each of the sorters stationed at a long bench has in front of him a fitting which contains 48 pigeon-holes into which he sorts the correspondence. When a pigeon-hole has been filled he takes out the contents, ties them into a bundle and drops it into the appropriate bag. You will say, of course, that letters have to go to far more than 48 places and that is true enough, but what is called primary sorting divides correspondence into sections for large cities and towns, and counties or groups of counties which have to be sorted again. Thus, you ought never to omit the county whenever you address an envelope, unless your letter is going to one of the largest cities. Further, London, Edinburgh and most of our biggest places are now divided into numbered postal districts and such a number ought always to be given because it helps the sorting staff and prevents delay.

The Distributing Office

In due time, when the mail as collected has been transferred from the boxes in the sorting "fitting" to appro-



Post Office

ALL PART OF HIS DAILY ROUND

In order to deliver letters to out-of-the-way places, the Post Office have various methods of transport, some of which are not lacking in novelty In the picture above the postman is seen just after crossing the River Findhorn at Nairn in Scotland The one-man power transporter bridge has just come to rest on its platform after the crossing

priate bags, it is dispatched by road and rail, and it may be said that the majority of the bags find their way as quickly as possible to what is known as a distributing office, of which there is at least one in every large district. Here there is more detailed sorting and bags are made up for all the places in the district, whether they are large or small.

Finally, there is the postman who delivers your letter in the area which he serves, the route most carefully arranged to save delay and known as the official's "walk." He takes his letters from the sorting boxes and arranges them according to the streets he has to traverse, tying them in convenient bundles for the purpose. Many postmen leave distributing offices by six in the morning and it is by no means uncommon for the first delivery of the day to be in full swing by seven o'clock.

When one considers that many of these letters were posted only the previous evening, perhaps hundreds of miles away, how is the miracle of such swift and efficient transport to be explained ? It may well be, in the near future, that aeroplanes will shoulder some of the burden of the inland night mail, but at present most of the correspondence is carried by passenger train In the case of at least forty-three railway expresses, special postal carriages are attached and the sorting of letters in these carriages goes on all through the journey. These postal carriages are called T P.O.'s (Travelling Post Offices).

What may be termed the main arteries of the night mail system are two trains which run between London and Aberdeen. These twin services are wonderfully organised entirely for postal purposes, except that passenger coaches are attached between Perth and Aberdeen in both directions

Post Office

THE LINE-SIDE APPARATUS

' rom special postal trains and from many expresses mails are dropped and picked up at great speed with the help of this ingenious apparatus at the side of the line.

The train long known as the Down Special T.P.O. leaves the L.M.S. London terminus of Euston every evening throughout the year, with the exception of Christmas Day and Boxing Day. It is always drawn by one of the heaviest and most powerful engines and consists of at least six postal coaches and as many again of ordinary brake vans—a dozen long vehicles in all. The guard is the only railway official who travels on the train, everyone else being a Post Office worker. Thus, the crew comprises a supervisor, who is in charge of the whole staff of over forty sorters and two postmen to work the mail changing apparatus.

Actually, this apparatus is perhaps the most striking feature of the train. Outside the six letter vans, flat against the panelled sides, are two powerful electric binnacle lamps which serve to illuminate white boards set up as lineside markers. At speed and when rounding a curve the lights give a snakelike appearance to the train. There are only a few stops on the long journey but at nearly a hundred points bags of mail are discharged from the train and others picked up.

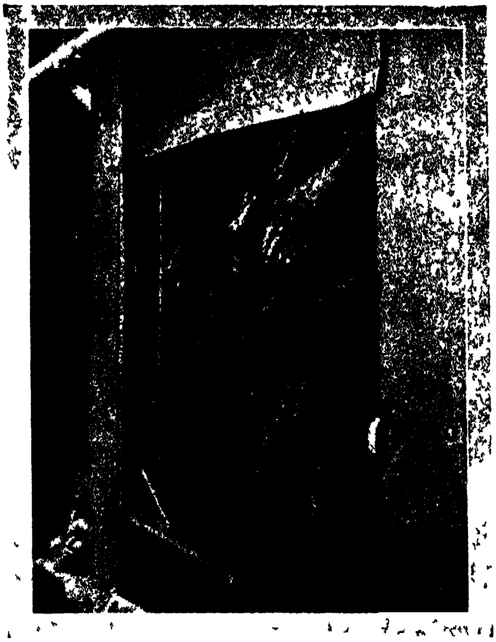
If you can imagine the Down Special approaching one of these points, a postman will be standing at the open door of a coach with only an iron bar between him and the trackside, which is being left behind at the rate of a mile a minute or more Like all the travelling staff, he knows every inch of the line whether the night be clear or foggy.

Presently, he detects a white board close beside the line and this serves as his signal. Immediately he fixes his pouches on to the dispatching arms of the apparatus; and, a moment later, pushes down a lever to open his receiving net A bell then rings to warn the staff to keep clear of the door

Fox Photos

AWAITING THE MOMENT

Here we see the men standing by with the mail-bags all ready to be ejected from the train and received by the net on the ground at the side of the railway.



Fox Photos

SAFELY COLLECTED

The receiving net has caught the bag suspended from the rail-side apparatus and the photographer has snapped it at the moment when the mail-bag is falling safely inside.

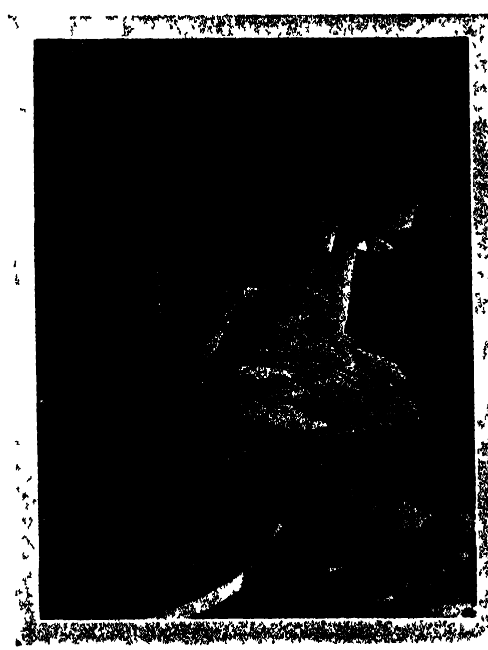
Dispatching and Receiving Mails

It should now be explained that at the side of the railway is an apparatus corresponding with that on the train. Rising from the ground is a tall standard, with its top arched over like a gallows, from which a pouch containing bags of mail is suspended.

As the train sweeps by this pouch is caught in a capacious net so shaped that the load it catches is thrown through the open door of the passing coach, where it falls thuddingly upon an immensely thick mat. On the train is a dispatching arm much like the gallows ; and, on the ground, a net is set to catch the pouch. In this way, by spacing out gallows and net at appropriate distances at the line-side the exchange of pouches is made automatically, the dispatching arms swinging back into the resting position whilst the net is brought flat against the train merely by the movement of a lever. And, on the railways of this country, there are no fewer than 97 of these apparatus points.

In this magic handling of mails, there may be two, three, four or more of the familiar canvas bags. How many there are does not matter so long as the total weight does not exceed 60 lbs. for dispatches from T.P.O.'s or 50 lbs. for dispatches to T.P.O.'s. Each mail bag is secured with a leaden seal and the whole consignment then placed in a pouch of enormously thick hide, kept pliant and waterproof by frequent oiling The pouch itself weighs 20 lbs. and one is not surprised at the reverberating thud with which it is thrown into a carriage on a train travelling perhaps at seventy miles an hour.

To begin with, the Down Special T P O. is well loaded with mails which reach it from most of the postal dispatching offices and railway termini in London. Loading begins an hour



Fox Photos

GOOD-BYE TO THE T.P.O.

The Special T P.O has reached one of the big stations and the mail-bags, sorted and made up for different districts in this area, are being collected from the coaches

before the train's departure, the bags to be sorted first being placed in the most convenient parts, with those for later sorting behind them. Bags of mail already sorted for particular destinations go mostly into the brake vans and there is on the train a posting box in which you can drop your own letter for a ½*d.* Late Fee.

Inside the long train as it thunders through the night the postmen are kept busy all the while, preparing for dispatch mail bags that are ready and taking to the sorters bags that have been picked up on the journey. As for the sorters, they are constantly at work for some thousand bags must be handled between the Metropolis and the far north. Except for the windows in the carriage doors there are no others on this train for the walls of the coaches on one side have sorting frames each made up of 54 pigeon-holes, the upper ones having glass bottoms so that no precious letter may be left behind because it has not been seen.

There are no names of places on these pigeon-holes but merely numbers, and each sorter knows his own plan so thoroughly that the numbers are sufficient. On the other side of the carriage are many hooks from each of which is suspended a labelled bag. Thus, as bundles are sorted, they are dropped into their proper bags.

The Registered Mail

In one section of each coach, under a senior officer, the registered mail receives attention. In other sections, long large envelopes, packets, newspapers and anything unsuitable for the pigeon-holes are sorted from zinc-lined troughs not unlike kitchen sinks into special sorting frames with larger apertures than those provided for ordinary letters. There is no sorting of parcels on this train, but at least one of the brake vans is devoted to the needs of the Parcel Post. It is hard work sorting on a T.P.O., but the staff responds loyally to whatever pressure is imposed upon it.

Crewe is the hub of our inland postal wheel. The Up and Down Specials between London and Scotland both stop there, though for only a few minutes. Between 11 p.m. and 2 a.m. no fewer than nine T.P.O.'s attached to passenger expresses stop at this vast junction. Here mail services from Ireland, East Anglia, the west and north of England and of course Wales dovetail into one another, together with postal traffic from London and the south. No wonder there is a depot at Crewe, where spare parts of every kind for the instant repair of mail-changing apparatus are kept to meet any emergency. Two other special P.O. trains are those which run nightly in each direction between Paddington and Penzance.

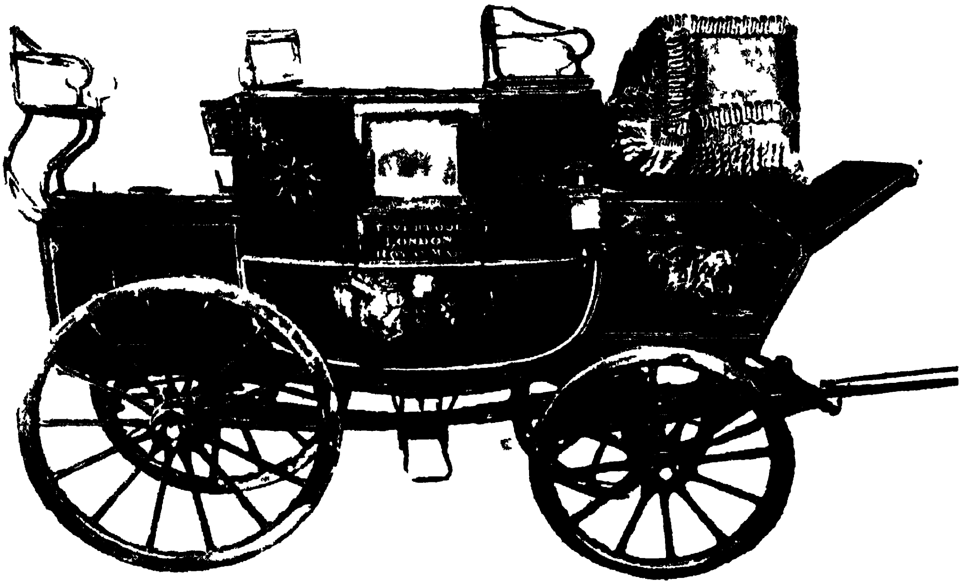
A P.O. Underground Railway

So far as London goes, the chief sorting office of the Inland Section is at Mount Pleasant and some twenty millions of letters pass through this one centre every week. Here one finds mechanical conveyors of every kind to take correspondence from the stamp-cancelling machines to the various sorting and bagging positions, and it is interesting to know that the G.P.O. has in London its own underground railway, which naturally relieves the busy streets of still further congestion.

The line itself is upwards of six miles in length and connects Mount Pleasant and other sorting offices with several of the railway termini. Forty driverless electric trains run every hour in peak periods, some 80 feet beneath the capital's highways, and they normally carry 35,000 bags of mail a day. Further, the Post Office owns at least 21,500 motor vehicles, nearly 9,000 being used for the transport of mail alone, besides those hired from contractors and leaving out of account horse-drawn vehicles.

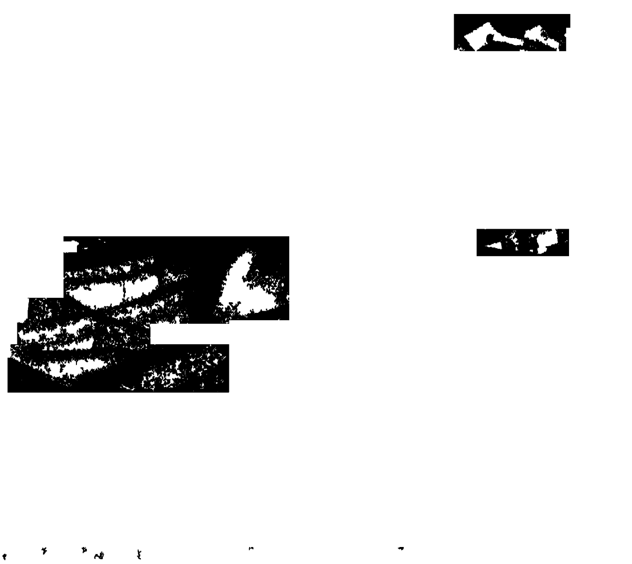
The efficient carrying of the Royal

A MAIL COACH OF 1832



Clarke and Hyde

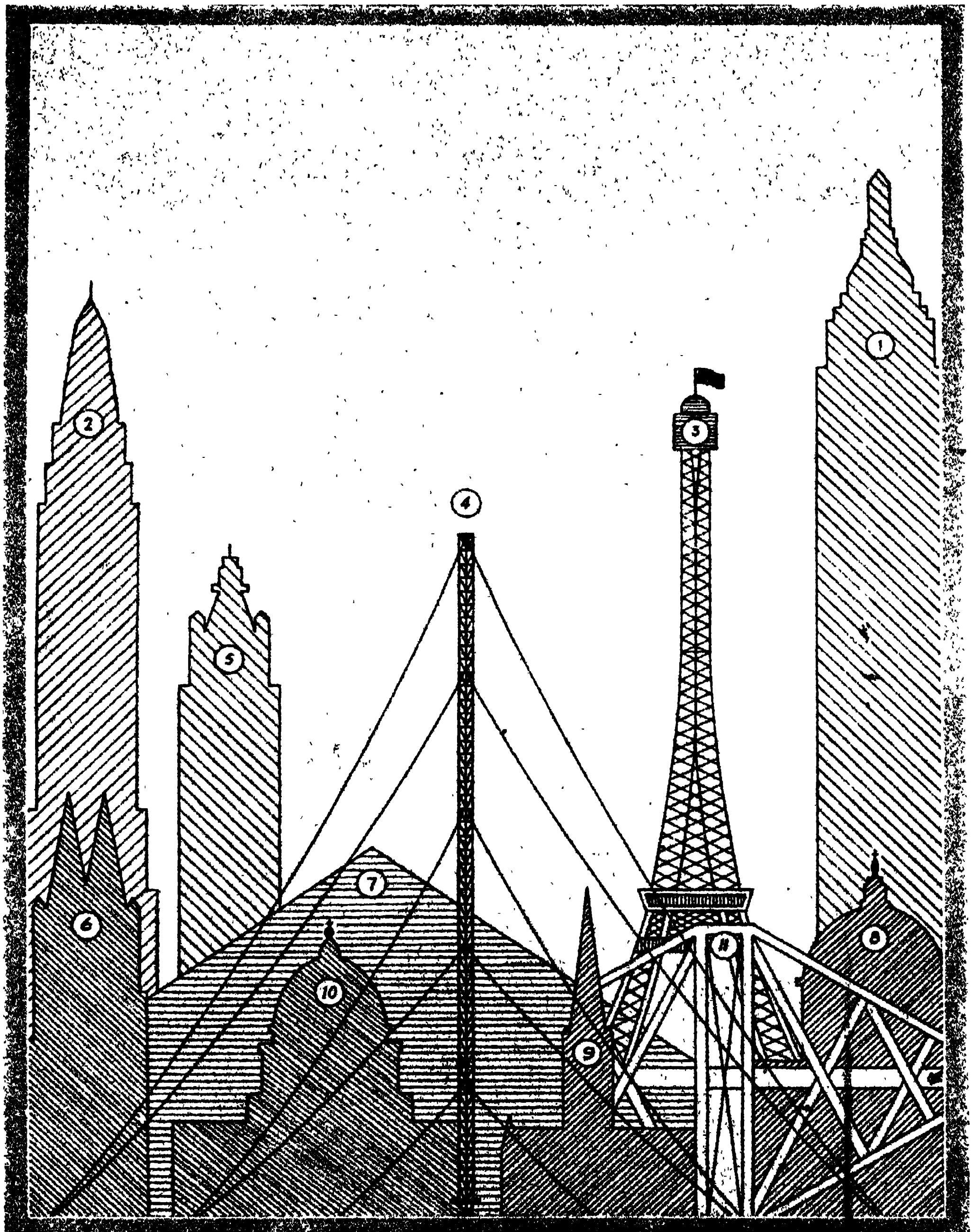
Couriers carried letters under an organised system even in the days of Ancient Rome, and in England there were posting houses in the reign of Edward I. We had our first regular inland post in 1635 and the G.P.O. was created in 1657. Yet not much more than a hundred years ago mails between London and Liverpool were carried by coaches, one of which is here depicted.



Post Office

In this picture the sorters have paused for a moment to give the photographer an opportunity of recording the scene at London's chief Parcel Office at Mount Pleasant. It was taken at a time when the Christmas pressure had just begun and as soon as this collection is cleared another will be ready for the sorting staff.

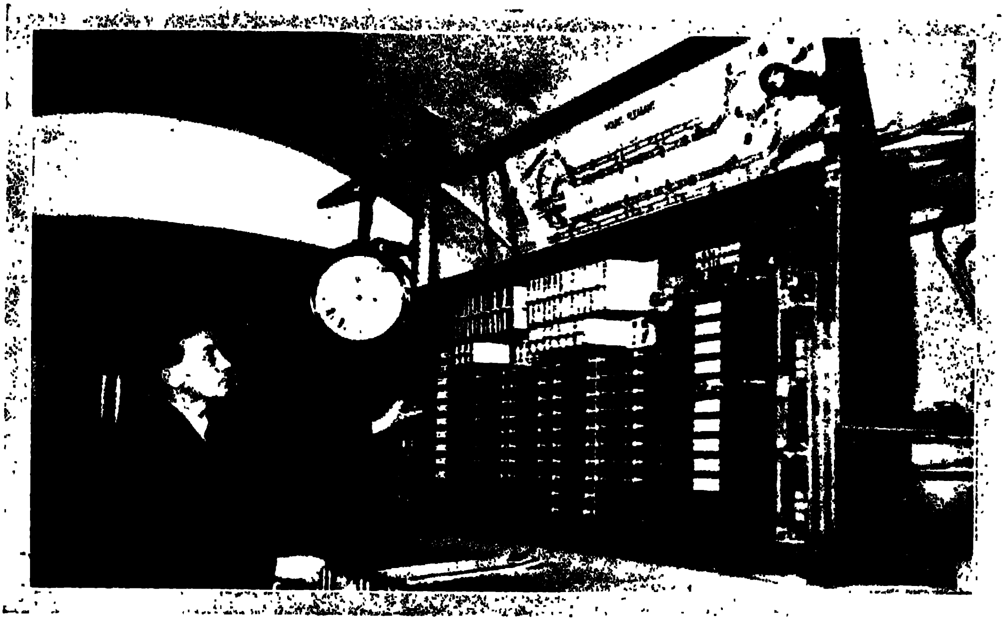
COMPARING RUGBY RADIO MAST



Post Office.

In this drawing the heights of some of the well-known high buildings and other erections in different parts of the world are compared with one of the Rugby Radio Masts. They are: 1, Empire State Building, New York, 1,248 feet. 2, Chrysler Building, New York, 1,100 feet. 3, Eiffel Tower, Paris, 985 feet. 4, Rugby Mast, 820 feet. 5, Woolworth Building, New York, 792 feet. 6, Cologne Cathedral, 515 feet. 7, Great Pyramid of Cheops, 450 feet. 8, St. Peter's, Rome, 448 feet. 9, Salisbury Cathedral, 404 feet. 10, St. Paul's Cathedral, 365 feet. 11, Forth Bridge, 361 feet.

LONDON'S SPECIAL POSTAL RAILWAY



In order to hasten its work the Post Office possesses its own tube railway far below the streets of London. The line runs between Whitechapel and Paddington, connects most of the important postal departments and deals with 35,000 bags of mail a day. The driverless trains are controlled by an official, as illustrated above, who operates a switchboard at Mount Pleasant.

Post Office.

Our picture affords you a glimpse of one of the underground stations on the P.O. railway and shows loading in progress. The trains run on narrow-gauge rails and attain a speed of 35 miles an hour. We should remember what a vast number of postal vans and lorries this tube railway keeps off the congested streets of Central London.

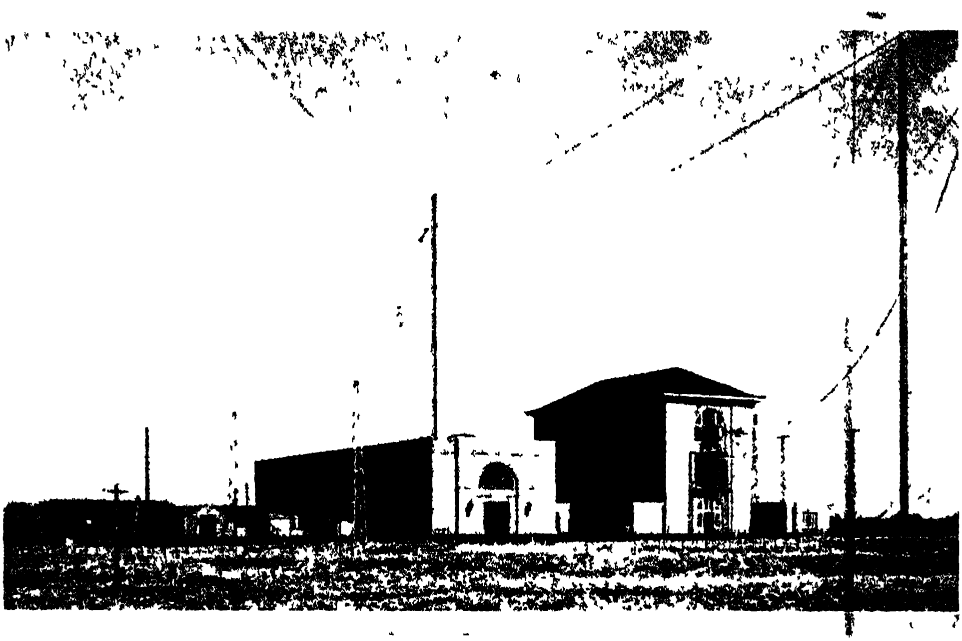
Mail is, as we know, but one part of the work of the G.P.O. Did you realise, for instance that the British Post Office provides facilities for telephoning by submarine cable to most of the countries on the Continent of Europe and by radiotelephone to the United States of America, South Africa, Canada, Australia, India and many other parts of the world, as well as to certain ships at sea?

The P.O. radio transmitting station at Rugby is one of the most powerful in the world, the station itself covering a site of 900 acres. The aerial is three-quarters of a mile in length, supported on four insulated steel masts each 820 feet in height. One must not forget, either, how the G.P.O maintains a marvellous radio-telegraph service, having no fewer than twelve wireless stations round our coasts. This service is of the utmost importance to ships at sea.

The G P.O. is also responsible for well over three hundred submarine cables, over forty of them connecting Great Britain with the continent of Europe. Such cables connect Northern Ireland with Scotland and Scotland with many of its outlying islands; they also link up the Isle of Man, the Channel Islands and Eire with Great Britain.

Something like 345,000 men and women are employed by the G P.O. and in this country there are about 25,000 Post Offices.

You go to a Post Office to buy a licence for your dog, gun, wireless or even for your car; to obtain a money or postal order; to transact business through your Savings Bank account or purchase National Savings stamps or certificates, to collect your pensions and allowances, or to buy Insurance stamps—and all this in addition to ordinary postal, telegraph and telephone business. Truly, the General Post Office is one of the most marvellous of all our public institutions.



Post Office

AT RUGBY RADIO STATION

The Post Office radio transmitting station at Rugby is one of the most powerful in the world and provides radio communication with almost every part of the globe The station itself occupies a site of 900 acres, and our photograph shows the main building with two of the four great steel masts, each of which is 820 feet in height.

HOW ELECTRICITY IS SUPPLIED

Fox Photos

A MAZE OF CONDUCTORS

A view at one of the main power stations feeding the vast network of electric mains, called the "grid," which now covers a great part of the country. The steel lattice-work supports horizontal insulators, of great length, to which are anchored conductors designed to carry current at the enormous tension of 132,000 volts. The whole of the electricity supply industry in Great Britain is now controlled by the British Electricity Authority.

EARLIER in this volume we have read how long years ago scientists experimented with electricity and discovered the peculiar properties of the magnet. At that stage of course they had no practical value but when men such as Michael Faraday carried their experiments a few stages further it was realised that there were still greater possibilities of a practical nature in these discoveries.

Two men, Joseph Wilson Swan in England and Thomas Alva Edison in America, share the credit for producing the first electric lamps suitable for use in homes and offices. There had been other lamps before this, however, and the Holmes arc lamp, driven by the Holmes machine, blazed out a beam with 1,000 candle-power from the South Foreland Lighthouse in 1858. It was not till 1878 and 1879 that Swan and Edison patented their new electric lamps.

There might have been trouble in the law courts between these two inventors but they settled their differences happily and the Edison and Swan lamps, known later as Ediswan lamps, opened up a new era for indoor lighting. In other directions, too, progress was made in the use of electric power; machinery could be driven by electricity, and the steam engine and the gas engine had a serious rival. By the beginning of the present century the new source of power and illumination had begun to be fairly well used and it might be said that the Electric Age had dawned.

An Ever-Increasing Demand

Some idea of the growth of the public electricity supply in Great Britain can be gathered from the fact that in 1921 the total units supplied by public supply stations to consumers of electric current amounted to just over 3,000 million units. In 1950 nearly 45,000 million units were supplied, the demand for electric current had increased some fifteen times in the last thirty years. It is all within this period that wireless sets, vacuum cleaners, cookers, washing-machines,

water-heaters and a host of other electric appliances had become articles of everyday use in thousands of British homes. Then, too, electric power was being used increasingly in steel-making and in many other industries.

It was all so easy; one just plugged in or touched the switch and the magic power did the rest. But this rapid development in the use of electric current created problems which the government had to tackle. In 1926 an Act of Parliament was passed to create a Central Electricity Board, and a National Grid system came into being around 1930. The object of this was to increase the amount of electric current available over the whole country and to enable it to be distributed fairly and more economically.

Big new power stations were planned and schemes for the development of electric power from water were mapped out. How these hydro-electric schemes have come into operation is dealt with more fully in the section "Electric Power from Water" in Volume V.

Some sixty-five years after the supply of electricity to the public was first mentioned in an Act of Parliament, the Electricity Act of 1947 provided for full public ownership and operation of what had become a great and expanding industry. This Act came into force in 1948.

In a Power Station

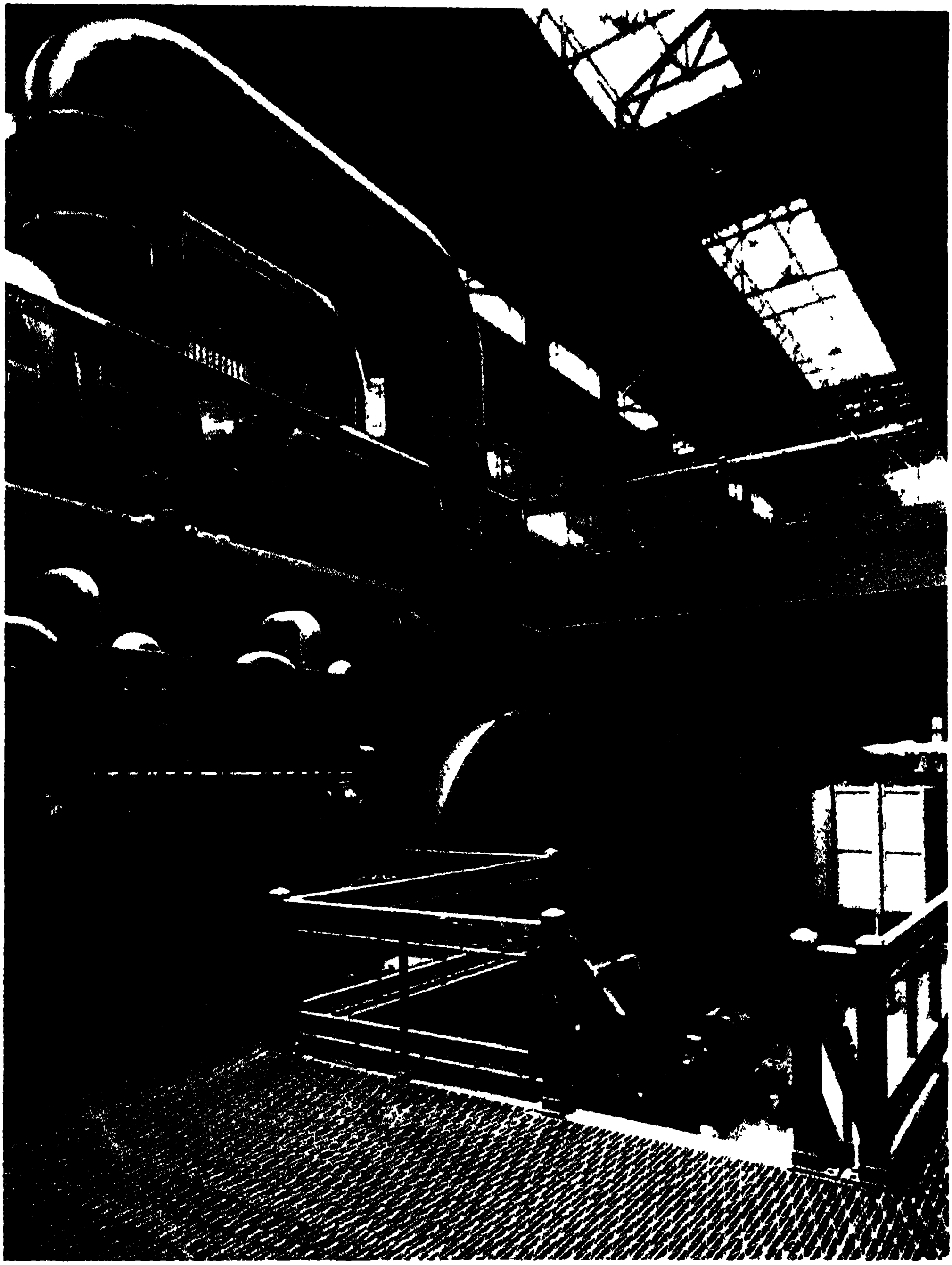
The history of the current which

British Electricity Authority

INSIDE THE TURBINE HOUSE AT BATTERSEA

The production of electricity on a large scale is based on a simple discovery made more than a century ago by Michael Faraday. This discovery led eventually to the building of our modern power stations in which turbines driven by steam produced by coal-burning drive large electric generators. In this photograph is seen the view inside the turbine house of A station at Battersea.

CONDENSING PLANT AT BATTERSEA



British Electricity Authority.

The pressure of the steam on the rotating blades of the turbines drives the wheels round at a high speed, usually either 1,500 or 3,000 revolutions per minute. By the time the steam has finished its task in the turbine its pressure and temperature have fallen and it is exhausted into the condenser, situated under the turbine, where it passes over numerous small tubes through which cold water is driven. The steam is thus condensed into water and pumped back into the boilers.

lights a lamp when you move a switch begins in a power station. In this country most electrical power is generated by steam obtained by burning coal in boiler furnaces. Water power is, however, being developed, especially in the North of Scotland, where water turbines drive electric generators and so enable more electric power to be fed into the Grid without using up more of our available coal.

A power station, as we know it here, is a great building, often found on the outskirts of a town, which gives out a loud humming noise, as of gigantic spinning-tops, from year's end to year's end. Close to it you may see great structures, somewhat like huge, squat chimneys.

These are cooling towers, used to chill water which has been heated by being circulated through condensers to change steam from the turbines back into water. If we could look inside a tower, we should see films of water trickling downwards over hundreds of thousands of wooden slats, and meeting a current of cold air rising through the tower. Many millions of gallons of water have to be used and cooled each day.

Some of these cooling towers are now fitted with eliminators which remove 95 per cent. of the vapour from the steam. In certain districts the clouds of steam from the cooling towers produced an artificial drizzle which could sometimes become a nuisance to people living in the near neighbourhood. The problem was studied by experts and new methods have been adopted which has already eliminated the trouble to a considerable extent.

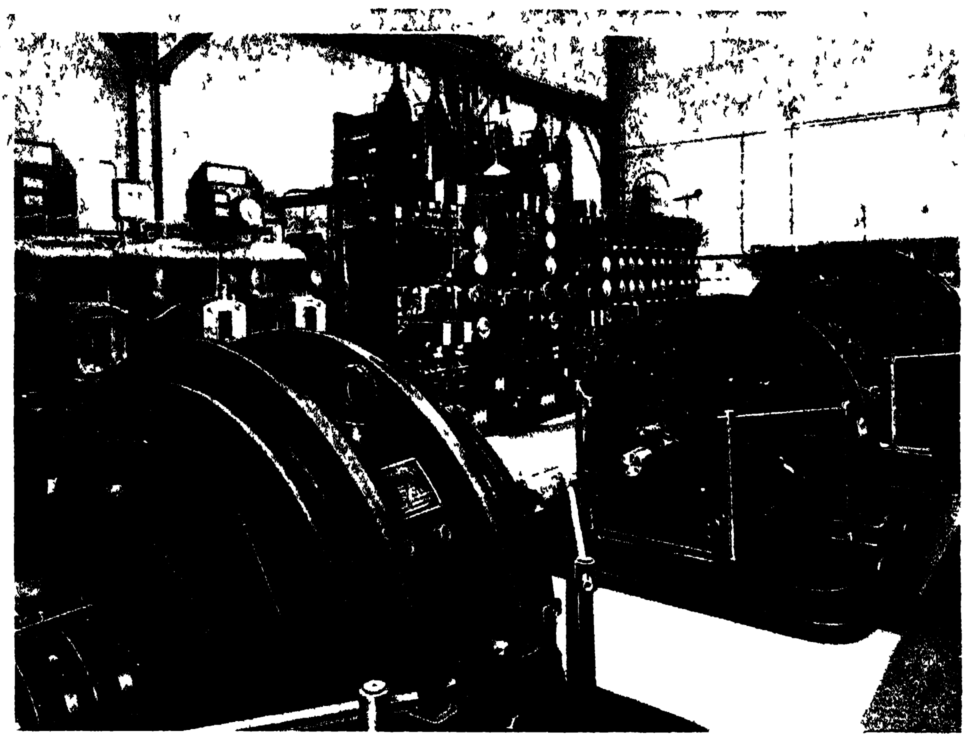
The Boiler Room

Steam is raised by a battery of water-tube boilers. A boiler of this kind is made up largely of tubes, inside which is the water, and among which the furnace gases pass In some stations one of these boilers may be as big as a

Morgan-Wells.

LIGHT AND POWER IN THE WORKROOM

When Thomas Hood wrote his *Song of the Shirt* he painted a grim picture of a garment-maker stitching with needle and thread by candlelight. In contrast to that non-electric age the photograph above shows a workroom where garments are made to-day with electrically-driven sewing machines and in the pleasant glare-free brightness of modern fluorescent lighting



Metropolitan Vickers Electric Co., Ltd

UNDERGOING A CHANGE

The high-tension alternating current generated in a power station must be changed into continuous current of much lower voltage to be suitable for use on our electric railways and tramways. This picture shows us three machines, called converters, used to bring about the change. They are, in effect, a combination of motor and generator. Alternating current makes them spin round, and their spinning produces continuous current.

good-sized house, and able to convert 200 or more tons of water into high-pressure steam every hour.

To give you some idea of what this means, let us explain that 200 tons of water would fill a trough a yard wide, a yard deep, and about 270 yards long. The coal for feeding the boilers is stored in great overhead bunkers, from which it passes down through shoots to mechanical stokers. These feed it into the furnaces at a steady rate. In some stations the coal is ground up into a very fine powder and blown into the furnaces in much the same way as oil fuel.

Among the Turbines

From the boiler-house we go into a huge chamber well lit through the roof. Ranged in orderly lines on its spacious floor are a number of steam turbines, each having its shaft connected to that of an electric generator. The turbines are entirely closed in, and the generator spins so fast that any visible moving parts are merely blurs.

There is very little to see here, as compared with the busy working of rods and cranks in the engine-room of a big steamer. But these quiet-looking and quiet-working turbines, on which one might stand a penny edgeways without it falling over, are doing great service. For every turbine-cum-generator unit may be converting anything up to 60,000 steam horse-power into electrical energy. One or more units may be standing idle, ready for starting up when the demand for current exceeds

a certain limit, or to give one of the others a rest for overhaul or repairs

Some distance from the turbine-room is the control-room, or switchboard room, containing panels which carry switch levers for controlling and directing the current, and instruments showing how much current is coming from each generator, what its pressure is, and so on. The switches themselves are, for safety's sake, housed in a separate building, and are operated from the panels by "distant control."

Photopress

MINIATURE LIGHTNING

This very interesting picture shows an electrical discharge taking place between an insulated ball and a plate on the ground. To cause the leap of only a few feet through air an electrical tension of a million volts was needed. One of the great difficulties associated with very high tension currents is that of preventing their escape from the conductors.

Through the Transformer

The current generated in the station is alternating; that is, keeps changing its direction through the circuit many times a second.

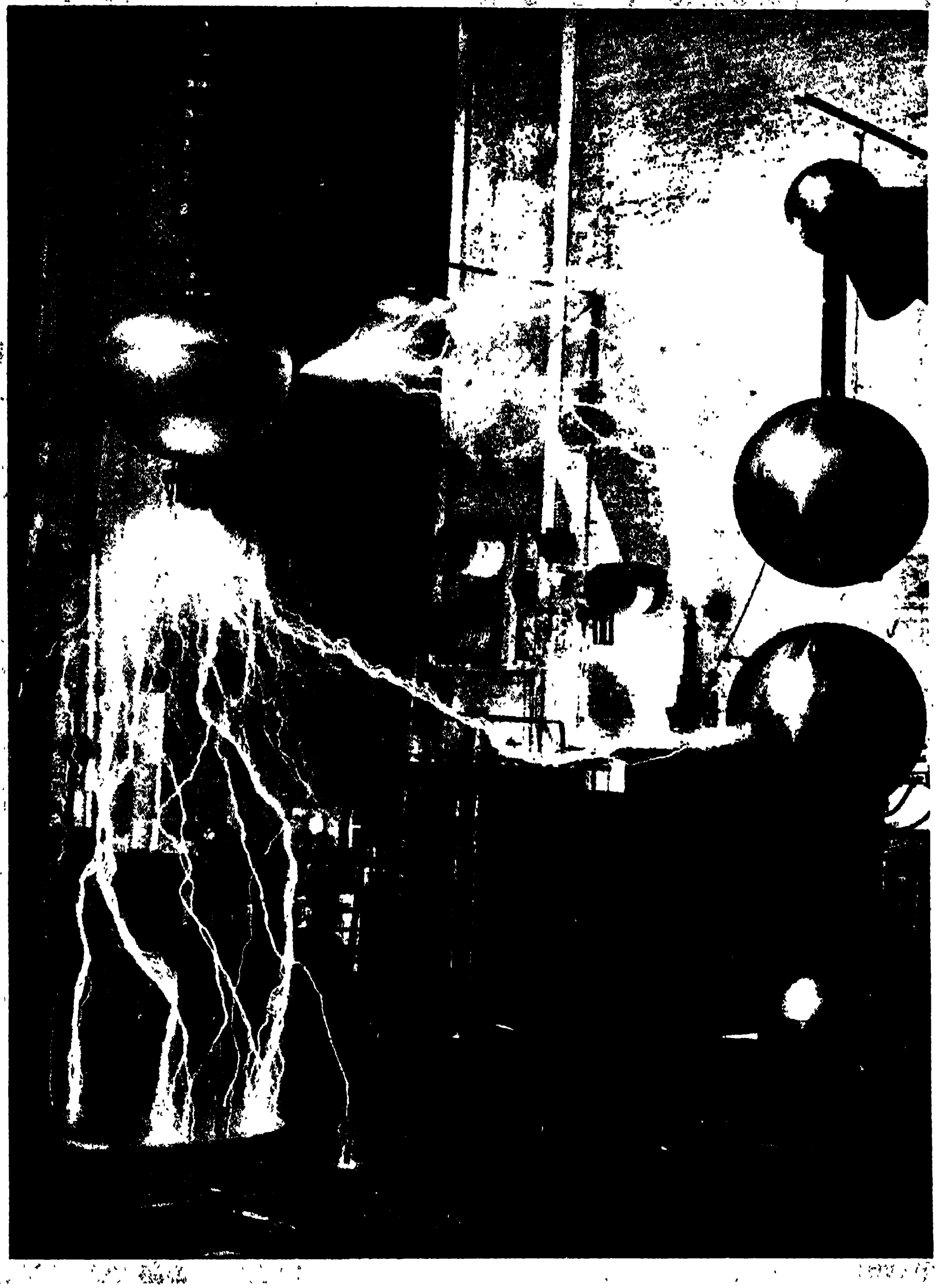
Alternating current is used because, by means of a simple piece of apparatus, named a transformer, it can have its pressure increased and its volume lessened, or its pressure lowered while its volume is made greater. One may compare the process with changing copper coins into silver coins in the one case, and changing silver coins into copper coins in the other. The value remains unaltered in both instances.

So far as electrical power is concerned, it makes no difference whether one uses a lot of low-pressure current or a smaller amount of high-pressure current. But high-pressure current is transmitted with less loss than low-pressure current through long conductors, while low-pressure current is much safer to use. So the transformer plays a very important part in the distribution of electricity.

We will assume that current is generated at the power station at 6,000 volts, a volt being the unit of electrical pressure, corresponding to the pound per square inch of steam in a boiler.

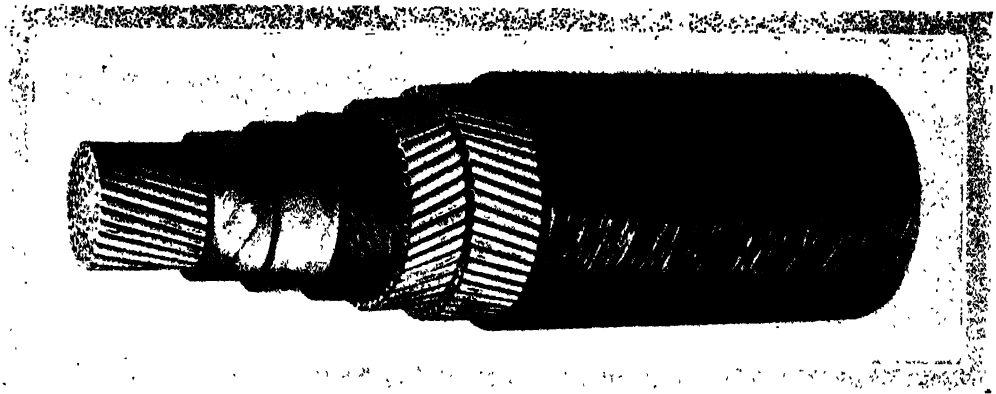
Distributing Current

If we follow one of the conductors running from a power station it may lead us to a converting station in a "tube" or other electric railway. Here a motor and dynamo in one—a converter, it is called—changes the high-pressure alternating current into

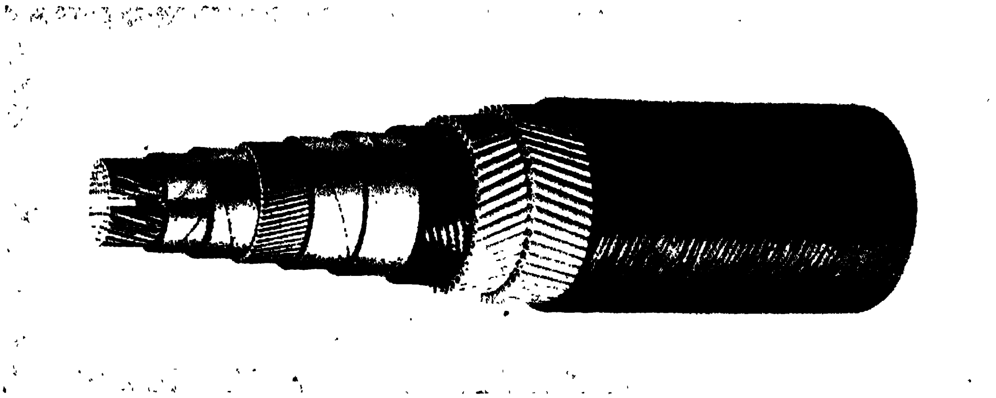


Fox Photos.

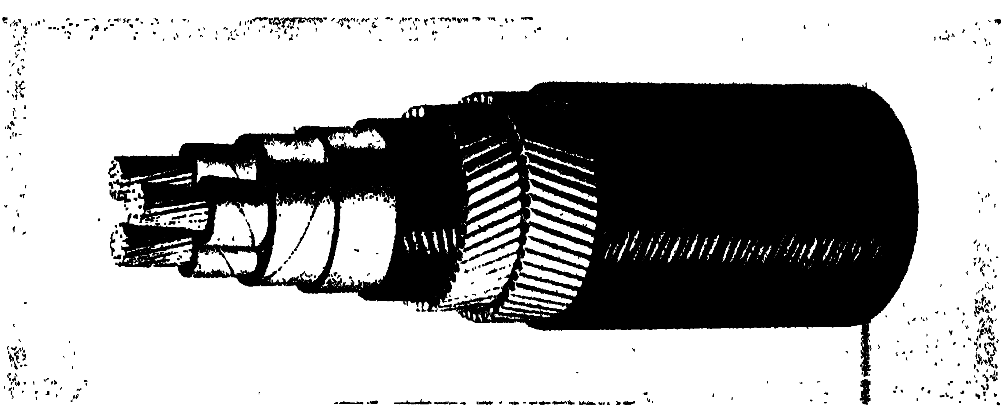
Another fine display of electrical energy breaking loose from its shackles. It is both streaming to earth in a cascade of fiery lines and leaping horizontally. You will note how closely some of the lines resemble lightning flashes, which are in fact the same phenomenon on a much larger scale, occurring between cloud and earth, or cloud and cloud.



This is an end of an electric power cable, "stepped" to show construction. The central many-wire conductor is insulated by a wrapping of paper strip. Outside this is a sheath of lead to keep out damp: and then in succession come a layer of jute serving two layers of armouring wire, and a wrapping of jute.



This cable has three conductors. Two, semicircular in section, are at the centre. Each has its own paper insulation, and the pair is further insulated by a wrapping enclosing both. Outside this wrapping are the wires of a third conductor, covered by paper, lead, jute, armouring, and more jute.



Photos: General Electric Co., Ltd.

In this three-conductor cable, designed to carry current at 11,000 volts tension, all the conductors are at the centre, insulated from each other and from the lead sheathing. The making of cables for the distribution of electrical power is now a very important industry.

HUGE ELECTRICAL SWITCHES

General Electric Co Ltd

These are three great steel tanks containing oil in which are submerged switches for breaking circuits carrying current at 132,000 volts The pressure and cooling effect of the oil prevent an electric arc forming between the parts of a switch as they are separated and destroying them The gear for moving the switches is operated from the control board by means which prevent the high tension current reaching the operator

continuous current at, say, 600 volts pressure, for working trains or trams.

Some of the power station's output, again, may be wanted by a distant town. In this case the current goes from the generators to a transformer, and has its pressure increased to 11,000, 22,000, 33,000, 66,000, or even 132,000 volts before entering the conductors. On reaching the town it is "stepped down" say, to 3,000 volts at a transforming station, for distribution through the town.

The 3,000-volt high-pressure conductors or mains run from the transforming station about the town, and are connected here and there with transformers housed in structures, called kiosks, usually placed in open spaces at road junctions. A kiosk is 8 feet to 9 feet high, a yard or so in diameter, and entirely enclosed with iron plates. It is often used as a lamp-standard. In it the current is stepped down to, say, 415 volts, and passed on to low-pressure distributing mains running down neighbouring streets. In many places they pass through disconnecting boxes, which sometimes are contained in square iron casings, a yard or so high, standing on the pavement near the kerb. These disconnecting boxes make it easy to cut any part of the mains out of the circuit when work has to be done upon it

The cables are lead-covered and armoured with steel tape, and are buried in the ground under the pavements. A cable contains three large conductors, with red, blue and white wrappings respectively, and a black-covered smaller conductor. There may be, and often is, a fifth conductor for special use as a switch wire for street lamps

General Electric Co., Ltd.

PUTTING AN ELECTRIC CABLE TO BED

Most power cables are simply buried in the earth, like water or gas mains This picture shows us one being drawn by a large gang of workmen into a trench the sides of which have been well shored with timber to prevent them falling in

When a house is to be connected up with the electric supply system, the low-pressure cable closest to it is opened, and a small twin-conductor cable running to the house has one conductor joined to "black" in the main, and the other joined to "red" *or* "blue" *or* "white." This gives a pressure of, say, 240 volts. "Black's" partner is not chosen at random A careful record is kept of all connections in a street, so that the total demand may be distributed as evenly as possible among the three "colours."

Somewhere in the street there may be a factory needing a large amount of power to

British Electricity Authority

ONE OF LONDON'S ELECTRICITY SUPPLY STATIONS

Among the modern landmarks of London is the Battersea Power Station with its fluted chimneys rising 300 feet above ground level The building itself 450 feet long, was designed by the distinguished architect Sir Giles Gilbert Scott Built in a populous area it was important to avoid poisonous fumes and the smoke passes through a filter plant which eliminates over 90 per cent of the sulphur

drive electric motors. In this case connection is made with "red" and "blue," "red" and "white," or "blue" and "white," "black" not being used Between any of these two the pressure is 415 volts

Electricity in the House

Now let us follow the branch cable to the house. After entering the house the conductors are joined to soft metal fuses which are designed to melt and break the circuit if the current should for any reason become dangerously great. Beyond these fuses—which the consumer cannot reach—is a meter for measuring the current ; and beyond that a main switch which enables the supply to the house to be cut off.

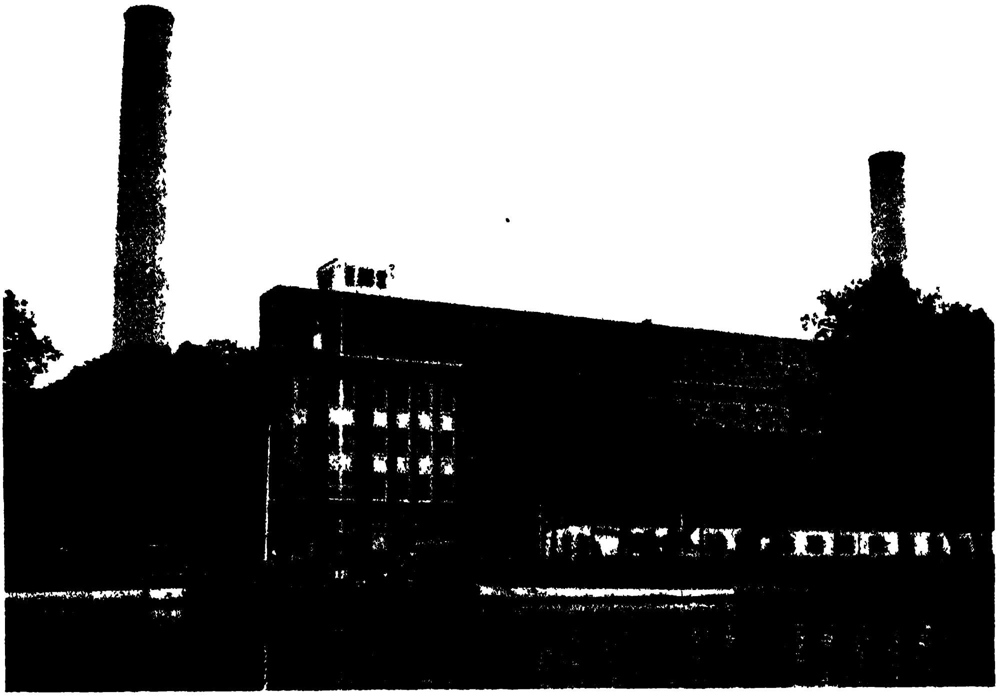
Then comes a fuse or pair of fuses, which the householder can inspect and replace when necessary Two wires connect these with what is called a distribution board, from which circuits branch out to various parts of the house Each circuit is protected by its own fuse or pair of fuses, mounted on a board. From the two wires of a circuit two branch wires are thrown out to each lamp and its control switch

We have now traced the distribution of electricity from the power station wherein current is generated to the points at which it is used.

Linking Up the Country

In the past the use of electrical power in Britain has been handicapped by the fact that power was supplied by a large number of quite independent companies, generating it at different pressures and at varying numbers of alternations per second. The result was that lamps, motors, and other electrical apparatus suitable for one district might be useless in another.

Imagine how difficult railway transport would be if each county had its



Central Press

A THAMES-SIDE POWER STATION

One of the great new power stations which have been built in recent years is seen here. It is at Kingston-on-Thames, Surrey, and the first section was opened by King George VI in October, 1948. Its capacity is 123,000 kilowatts, and, despite its strictly utilitarian purposes, it has not been allowed to become a mere blot on the landscape

own railway gauge, so that rolling stock in say, Sussex, could not be used in Surrey or Essex, and it were impossible to move locomotives from one part of the country to another.

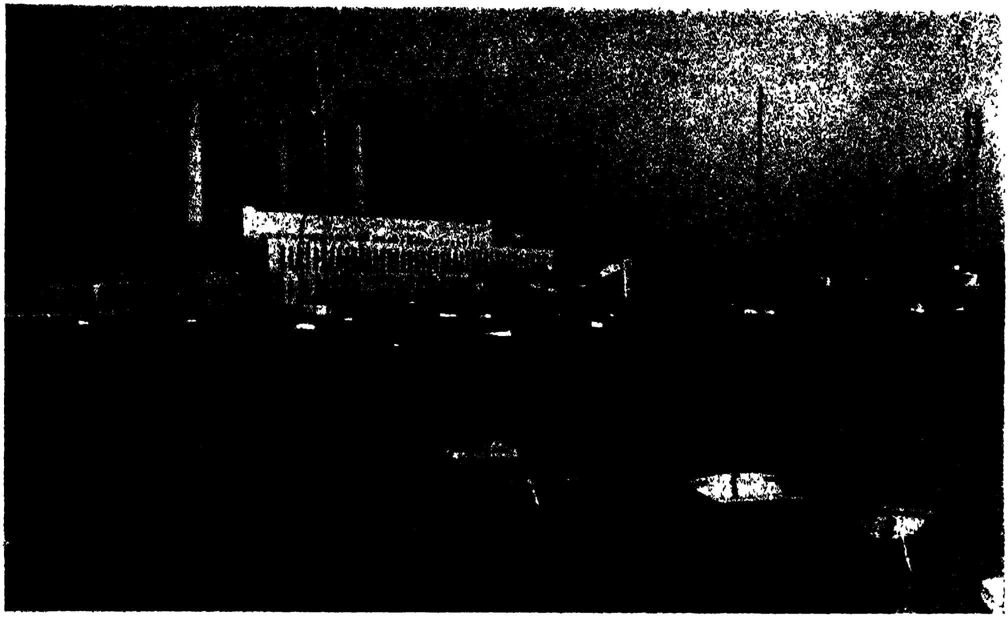
After the War of 1914-18 the question of bringing about a better state of things was taken in hand. Acts of Parliament were passed whereby all the 500 and more companies supplying power came under one great national scheme. A very large number of the old and less efficient stations were done away with, while some of the best were retained and their machinery standardised to produce current at fifty cycles per second. Large new stations were built in various parts of the country and the supply of electric current steadily increased.

The demand also increased and after the Second World War of 1939-45 the supply was often below the huge amount of current required by industry and in the home. There are times, indeed, when the current in different areas has to be cut off altogether. Whenever possible warning is given of the times when it may be necessary to cut off the supply for a short period.

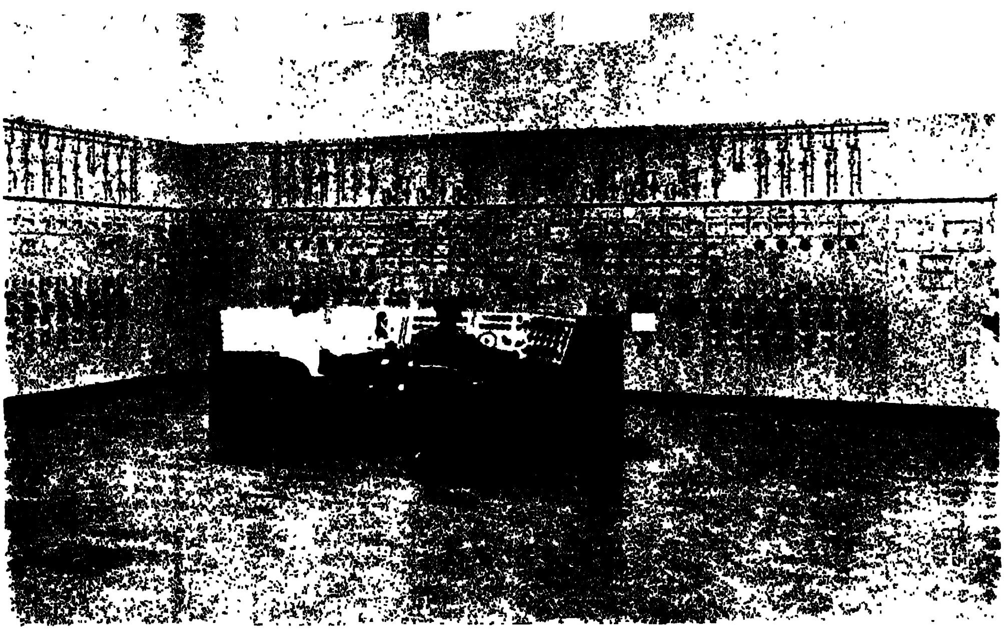
In order to carry the process of co-ordinating the supply of electricity to the whole country the Government decided to bring all the different undertakings under public ownership and from April 1st, 1948, the British Electricity Authority became responsible for the supply of electric current to the whole country. This national body with its headquarters in London is assisted by 14 Area Boards. There is a separate independent North of Scotland Board.

The big plans which were begun before the World War had to be sus-

AT CLIFF QUAY, IPSWICH



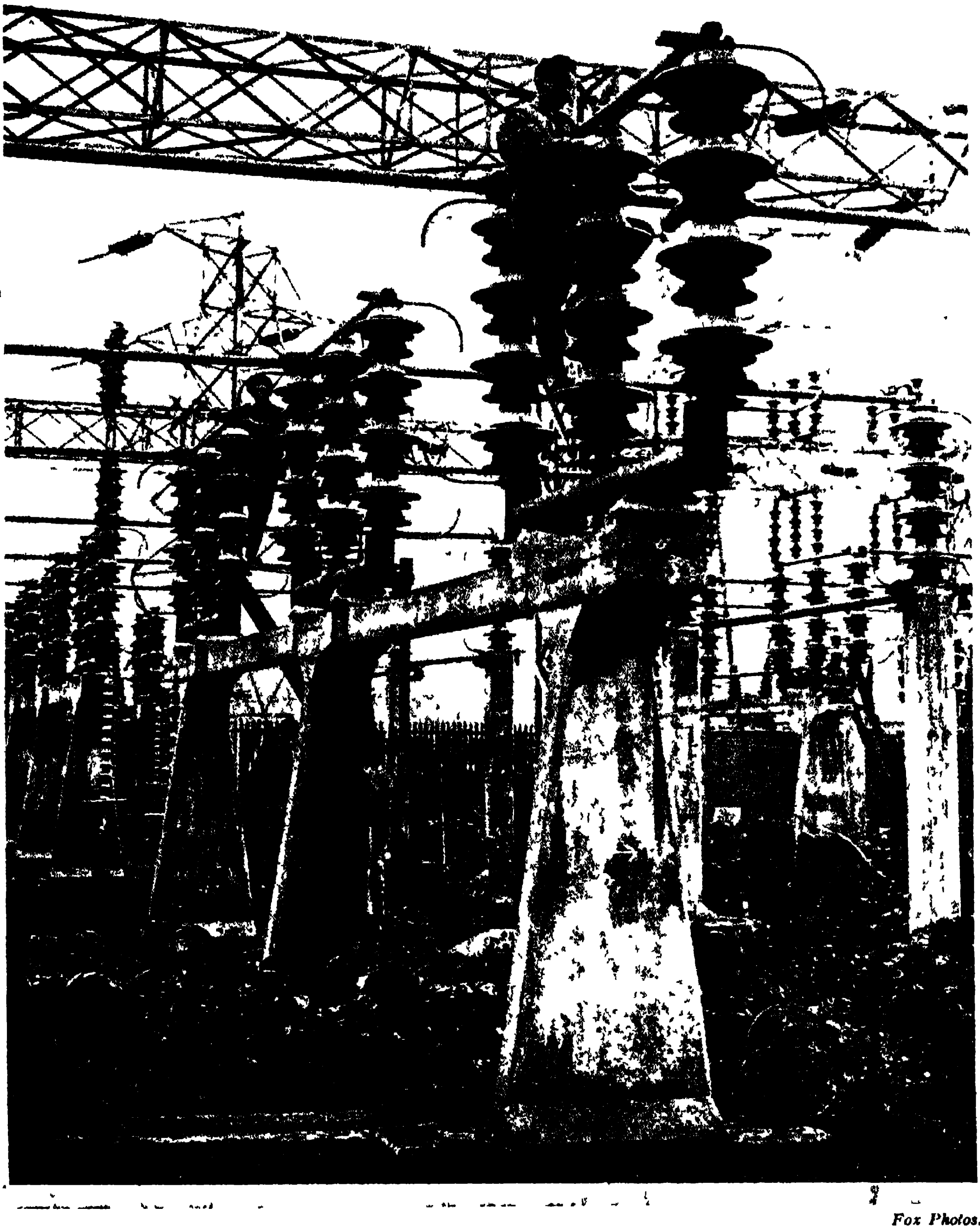
Another of our modern power stations in which the architect has nobly played his part is this station at Cliff Quay, Ipswich. Despite the great increase in the use of electricity the amount of coal used to produce the current is now only about one-quarter per unit compared with what it required 40 years ago and further improvement in efficient production is being steadily achieved.



Photos: British Electricity Authority.

Here we are in the control room of the Power Station at Cliff Quay, Ipswich. It is in this room that action is taken at the station on load-shedding when instructions are received from the Regional Grid Control Centre. The enormous increase in the use of electric current in recent years has imposed tremendous problems on those responsible for our supply of electricity.

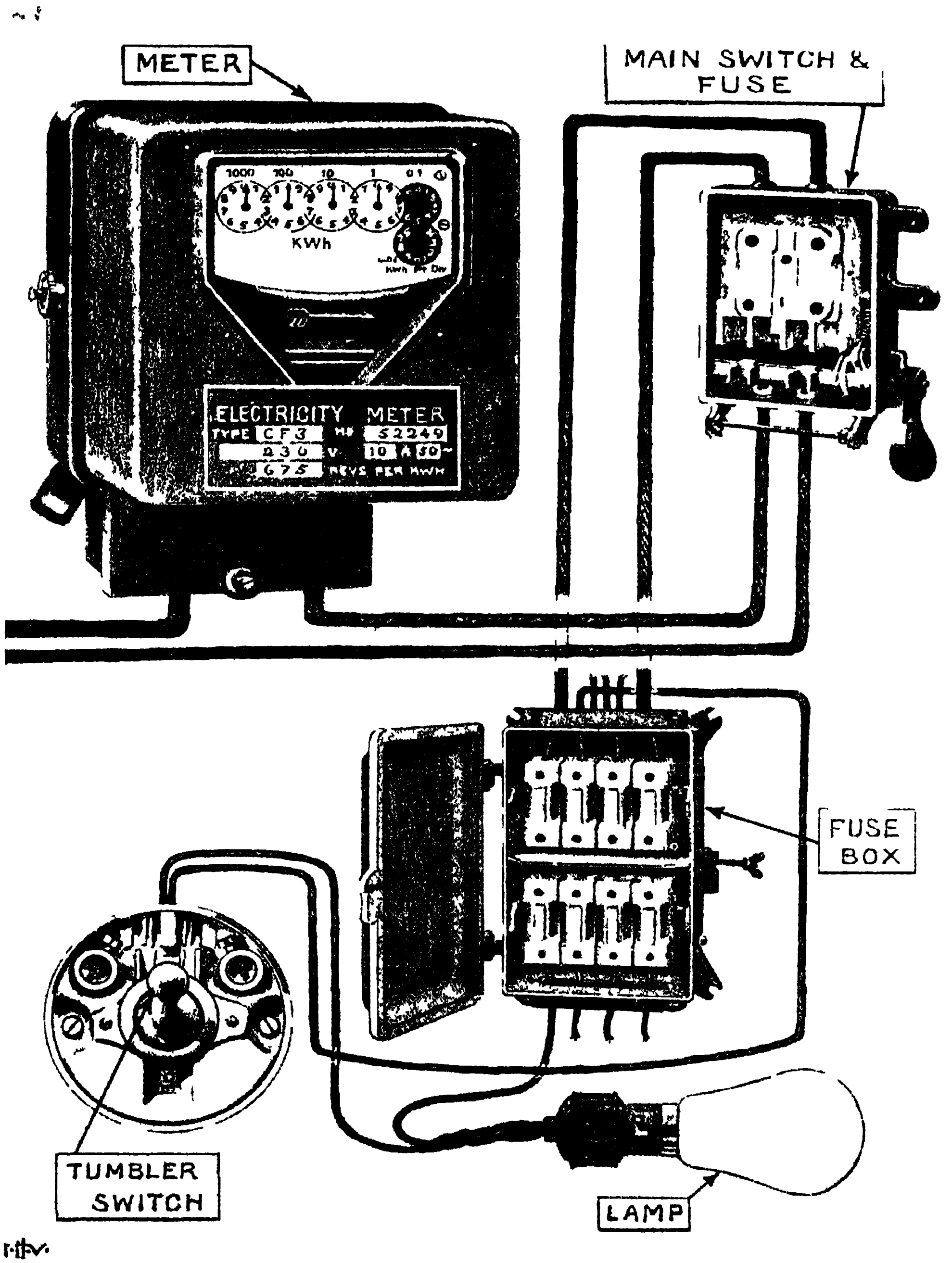
MAN-HIGH INSULATORS



Fox Photos.

The huge insulators seen in this picture are needed to prevent the escape of high tension current to earth Every such insulator has several "petticoat" storeys, each shaped to throw off water and keep dry on the under side. If the whole surface of an insulator were wetted, there would be serious leakage in rainy weather The insulators are made of a special porcelain, glazed on the outside

FROM THE METER TO THE LAMP



Specially drawn for this work

The current we use is first led through a meter which records on dials in kilowatt hours the electricity consumed. Next comes a main switch (operated by the lever on the right) for breaking both sides of the circuit and after this a pair of main fuses. At the fusebox the main circuit branches into as many sub-circuits, each guarded by its own pair of fuses, as may be needed. Every lamp on a sub circuit is controlled by a tumbler switch.

pended to a large extent while hostilities were in progress, but work was resumed as soon as possible when peace came. The most interesting feature of this great scheme for linking up the power stations in one area with those in another is, from an engineering point of view, the main network of conductors named the "grid." This is made up of about 4,000 miles of "trunk" lines, corresponding to the arteries of the human body. A line has three conductors, each about ¾ inch thick, and made up of thirty bare aluminium wires twisted round a core of seven steel wires which give it the necessary strength. The conductors are carried on lattice steel towers, usually 70 feet to 80 feet high, and set 900 feet apart, but larger ones are also used.

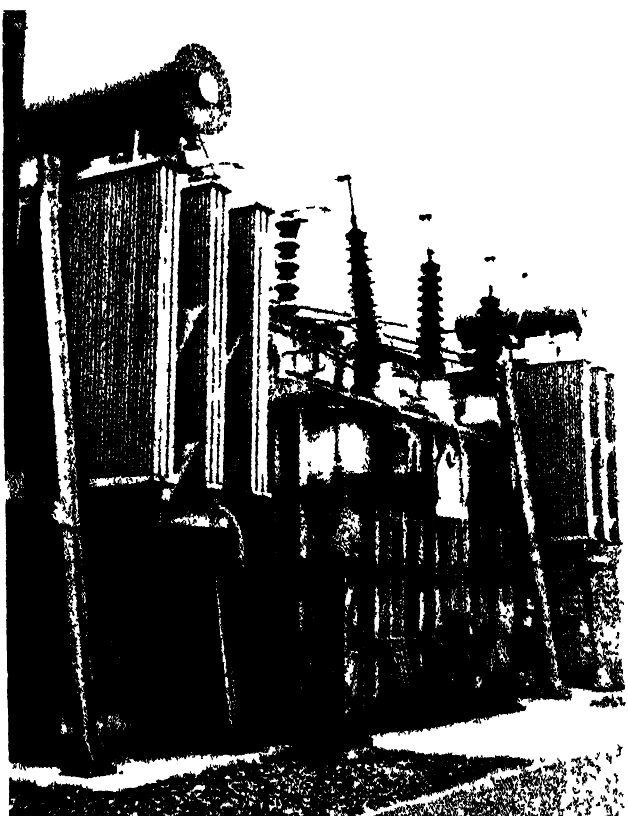
In some places, of course, the spans have to be much longer. At the crossing of the Forth, for example, a jump of over 3,000 feet is needed, and the conductors are supported by towers 358 feet high, to give plenty of room for ships to pass under them.

The electrical pressure in the grid is enormous—many hundreds of times greater than that used for ordinary electric lighting. So the conductors have to be kept well away from each other and from the steelwork of the towers. Between a conductor and the arm from which it hangs is a string of insulators, about 6 feet long, and the arms are so spaced that no conductor is within 12 feet of any other.

Some thirty-eight new power stations have been planned by the British Electricity Authority, and several are already in operation. In addition, a Super-grid employing an electrical pressure more than twice the original grid is now being constructed between Glasgow and London.

Besides the main grid there is a secondary network for distributing current, at half or a quarter of the pressure in the main grid, to centres where its pressure can be reduced.

Instead of having nearly 600 generating stations each supplying its immediate neighbourhood, we now have a comparatively small number of great power stations at work, each not only supplying its own neighbourhood, but able to contribute current to the grid arteries, to meet demands elsewhere.



British Electricity Authority.

"STEPPING-UP" THE VOLTAGE

By using high voltages on the national grid a great saving is effected. This photograph shows a transformer at a power station which raises the generator voltage from 11,000 to 132,000 volts to feed on to the transmission lines

TRANSPORT IN MANY LANDS

From animal transport to the steam locomotive was the first and most spectacular advance in transport. Electricity and the internal combustion engine have brought new marvels. Even mountains may be scaled in comfort by the method shown in the photograph above. This is a view of the aerial funicular which conveys passengers from the Rio Llabregat, below the town of Monistrol in the Pyrenees, to the summit of the "sacred mountain of the Catalans," which, according to tradition, is the site of the Castle of the Holy Grail.

IN MADEIRA'S SUN-KISSED HIGHWAYS

Ph t Keystone

The island of Madeira which belongs to Portugal is in normal times a popular holiday resort owing to its mild and salubrious climate It is a mountainous island, with steep twisting roads and narrow streets, often paved with pebbles Covered conveyances, known as *carros*, running on sledges and drawn by oxen, are still used, and our photograph shows this type of island transport

Photo Associated Press

The landing speed of an aeroplane makes a long runway essential, and the need for short-distance aircraft, able to land in confined spaces, is obvious In recent years the helicopter has been used successfully for postal work and as a taxi-plane Our photograph shows a British helicopter landing on the roof of a Paris store after a cross-Channel flight from a London roof-top.

ON INDIA'S COUNTRY ROADS

Photo Will F. Taylor

Motor-cars are as popular in India as elsewhere, but away from the cities and the well-kept roads animal-drawn vehicles still have pride of place. This photograph was taken not very far from Delhi. The travellers sit cross-legged on cushions, with a shell-like canopy as protection from the sun, while the carriage itself is decorated in bright colours, and the tinkling bells adorning the oxen provide musical accompaniment.

BY CAMEL CARAVAN TO CHINA

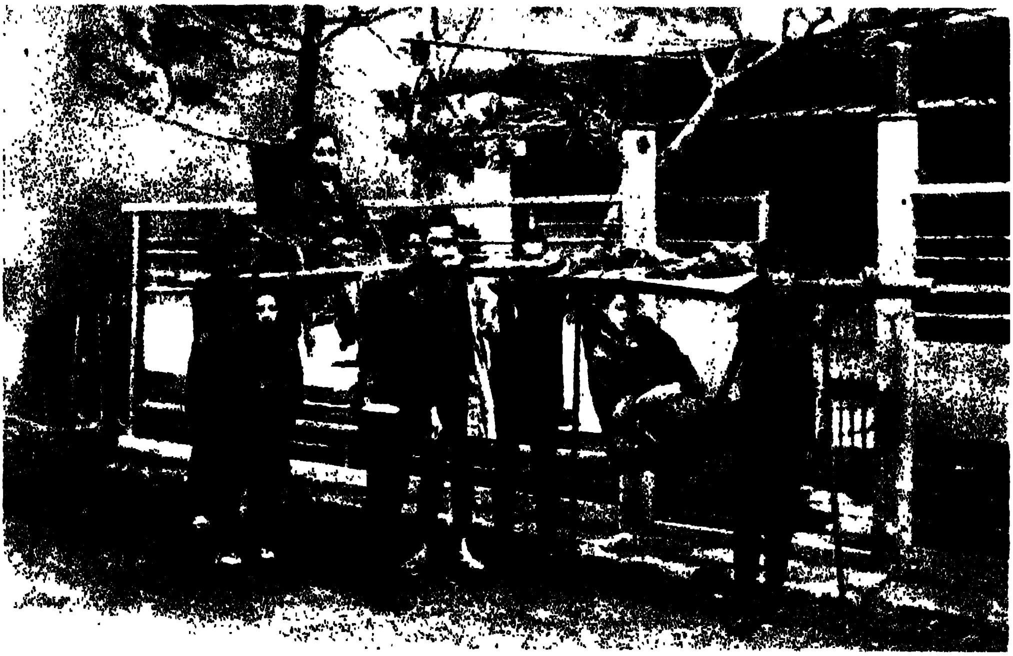
Photo: Mondiale

Our photograph shows a camel caravan on the road from Turkestan through the Kun Lun Mountains with goods for Hanchung and thence by river to Hankow. The bonnet of a car on the left suggests that modern methods of transport are not unknown on this ancient road, over which men and animals have travelled for centuries past.

Photo: Fox Photo

Egypt is the oldest civilisation in the world and in Alexandria, second city and chief port, founded in 332 B.C., East meets West and old and new mingle with the modern motor-car alongside a slow-moving animal-drawn cart. Here in this photograph an Arab stands in charge of a well-laden Yak, while in the background can be seen some of the modern buildings in Egypt's ancient city.

CONTRASTS FROM THE EAST



In many Eastern countries Western civilisation has introduced its modern inventions and utility attire. But the old methods are not disappearing too rapidly, nor has Western dress altogether ousted national costumes. In this photograph, taken outside an hotel in Japan, two guests are ready for an outing, one in a travelling chair while the other prefers a kago or palanquin.

We have seen a photograph taken near Delhi in a previous picture, and here in contrast we have a scene in the city itself. Electric trams have become one of the chief methods of transport through the streets of the Union of India's capital. The process of modernising the big cities has been going on for many years but there are still big areas where the bullock carts are the only means of conveyance.

Photo: Fox Photos

At first sight one would imagine that this photograph had been taken in one of the ancient lands of the East. Actually it was taken in Australia where there are great tracts of land across which the railways have still to be laid. Journeys over these sandy wastes must be made, however, and the camel still holds its reputation as the "ship of the desert."

Canada is another vast country where problems of transport are not easily solved. The task of bringing down great loads of timber from the big forests far removed from the railways is accomplished in various ways. In this photograph, taken at Hudson, in Ontario, can be seen the long line of heavily-laden trucks hauled by a tractor over snow and ice-bound roads to the distant rail-head.

BY CAMEL AND BY DOG CART

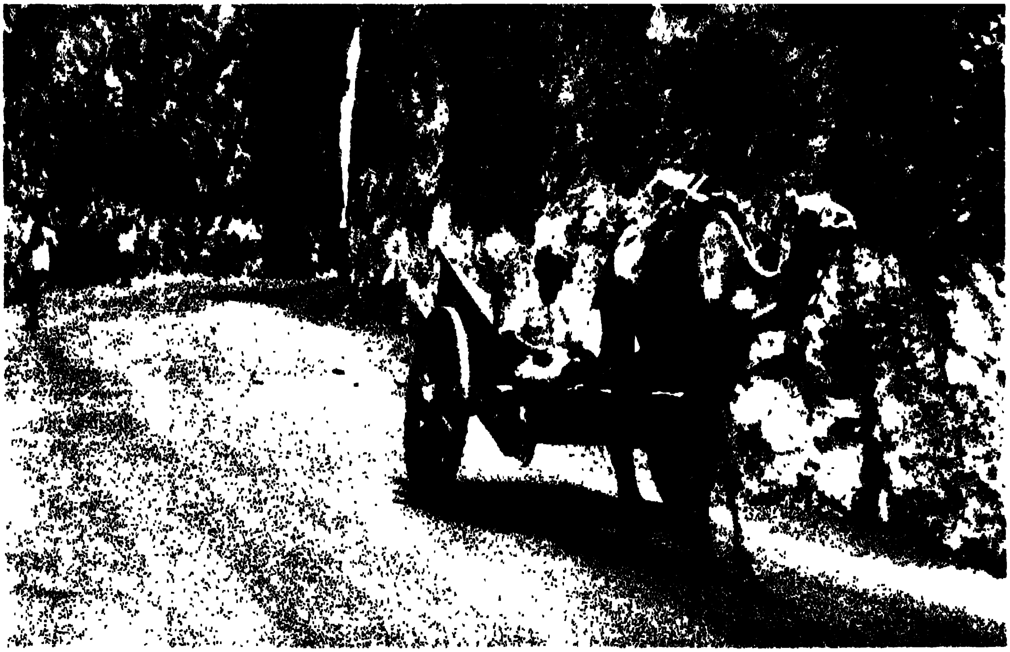
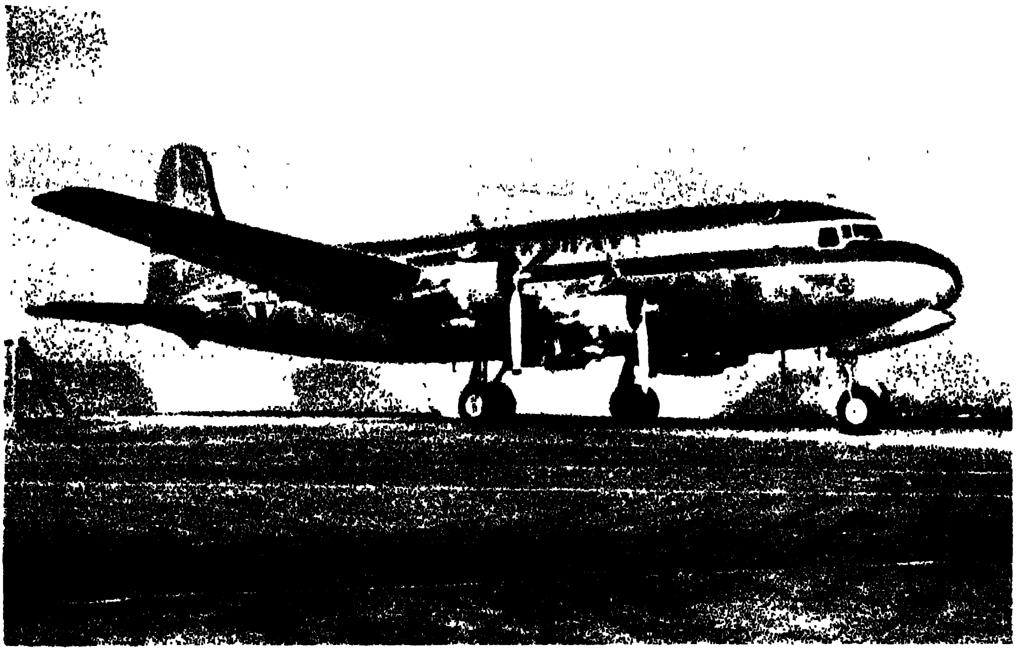


Photo: Fox Photos

In those lands where the heat of the sun presents its own problems the camel is still supreme. Here we have a photograph taken at Aden, near the entrance to the sun-drenched Red Sea, showing a camel cart which has been the means of transport in this part of the world through many centuries. A native trader drives into the port to collect his load of salt and cigarettes.

In Belgium and Holland dogs have been used for long years past to take round the morning milk carts in country districts. Despite more modern methods this form of transport still holds its own in many districts and has its peculiar advantages for fairly light loads and short distances with many stops on the round. Nor is the cost of upkeep a serious problem for the dog-owner.

SKYWAY FREIGHTER AND MODERN FERRYBOAT



In the mountainous country of California, the Golden State of the U.S.A., railway communication between the Pacific ports and the mining areas in the "back o' beyond" is not always possible. But airfields can be constructed in those areas difficult of access, and here we have a "skyway freighter" operated by the Santa Fe railroad, standing ready for the take-off at Los Angeles Municipal Airport.

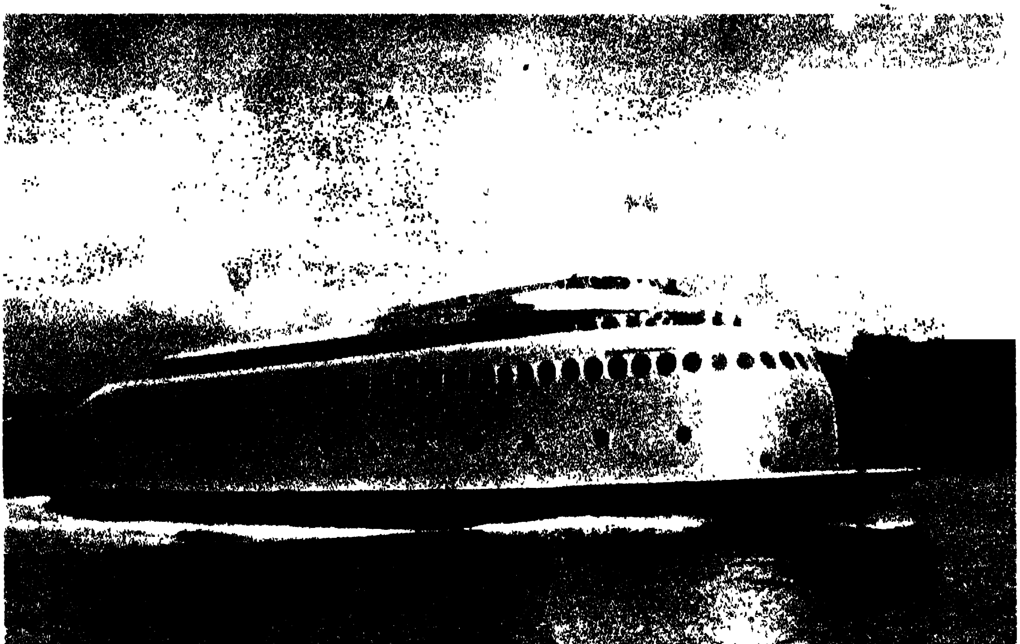
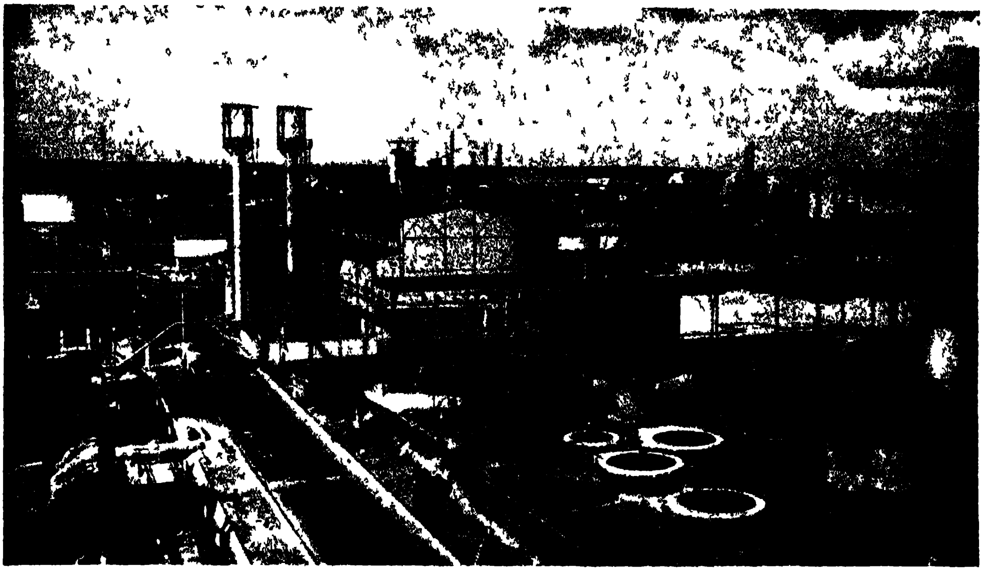


Photo: Dorien Leigh

On the far western side of the United States of America is Washington State, not to be confused with Washington, the capital, in the East. Puget Sound, which communicates with the Pacific, is a great inlet running into Washington State, and the simplest way of travelling between the big ports such as Tacoma and Seattle is by water. Our photograph shows a ferryboat for passengers and goods on the Sound.



Shell

AN OIL REFINING PLANT IN BRITAIN

Oil from Venezuela is brought to England in tankers and in the photograph above is given a view of the Ester Salts Plant at Stanlow, in Cheshire It stands on the Manchester Ship Canal In the distance can be seen the Mexphalte Plant and the tanker discharge berths The two Extraction Towers are on the left with the tank farm in the foreground.

THIS AGE OF OIL

PETROLEUM or rock oil has been known for thousands of years and the bitumen from it was used by the people of ancient Babylon to make mortar.

The Chinese knew something of the uses of oil more than 2,000 years ago and sunk deep oil wells from which they obtained their supplies. But in the Western World the value of oil as a fuel was not generally recognised until about the middle of the 19th century.

To-day, oil is one of the most important of all our raw materials. Even in the most remote countries of the world the petrol-driven motor car has been seen and the jungles in tropical lands are being cleared by petrol-driven machines. The waters of the seas of the world are to-day being churned by the propellers of oil-driven ships while in the skies above, aeroplanes cover vast distances at amazing speeds owing to their petrol-driven engines.

Oil was discovered in boring for salt, and was considered a nuisance because it seeped into the salt wells and spoiled them. Then someone found that raw petroleum was a ***lubricant*** ; that is, was good for oiling machinery. The result was that an oil-well was driven in the State of Pennsylvania, and oil was found at a depth of only 69 feet This took place in 1859 and may be regarded as the first oil well to be sunk

For Motor Car Engines

By degrees it was ascertained that

Topical Press

A STORE PARK AT A VENEZUELAN REFINERY

In comparatively recent years Venezuela has become one of the important oil producing countries of the world and her oil fields are being rapidly developed In this photograph is shown one of the store parks at a large Venezuelan refinery Here are stored over £2 500 000 worth of different equipment and spare parts, most of which is bought in Britain by the company owning the concession

the raw, sticky, ill-smelling stuff could be refined and used as lamp oil, and paraffin began to be burned in lamps Its use increased until in 1905 the world was using some 215,000,000 barrels of oil yearly. Then the motor car boom set in. The "internal combustion" engine came into its own and the world went oil-mad

The raw petroleum as it comes from the wells differs in quality according to the area in which it is found, just as coal differs in quality. Coal, we know, is the product of the forests of long centuries ago which have been buried beneath the earth's surface until through long ages they have been turned into this particular and highly useful kind of rock we burn in our fires

Just how oil came to be formed is not quite so clear. It is generally agreed, however, that it was formed during the course of millions of years from the large lakes which then existed. These lakes were gradually dried up as they became filled with decaying vegetation of all kinds In some strange way all this dead material has been gradually

changed during the long ages since it was buried beneath some great disturbance of the earth's surface into a greenish-brown or rather darker liquid known as petroleum or rock oil.

As it is pumped from the earth this crude oil would be of no practical use in the high-powered engines of to-day. It has to be refined and treated by the chemist in various ways according to the kind of oil required, and, of course, according to the quality of the crude oil obtained in any particular area. "Refining" covers various kinds of treatment, but it is from the crude oil that the refiners obtain paraffin for lamps and stoves, petrol for the internal combustion engine, diesel oil for the big engines in ships as well as heavy lorries and 'buses, and lubricating oil for many purposes. Jet-propelled planes require their own special fuel, a heavier grade oil more like paraffin.

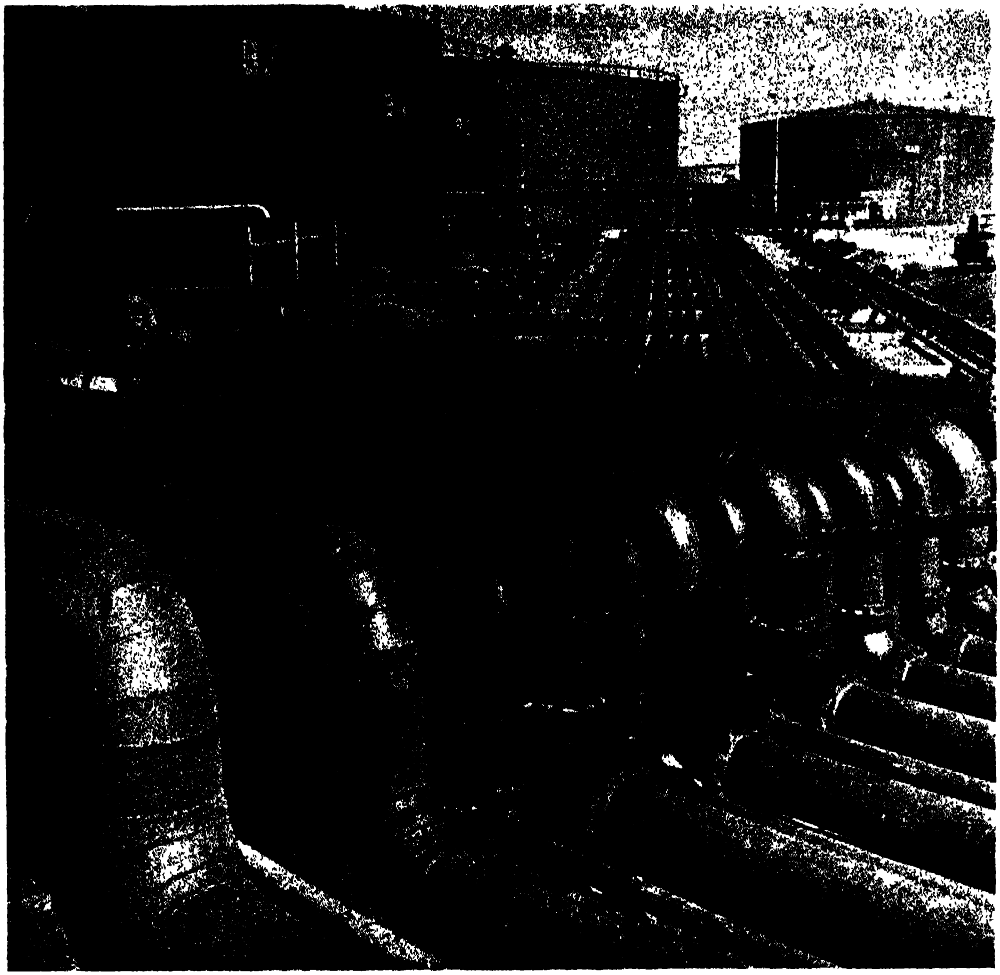
There is, too, the "high octane spirit" which is the outcome of the chemist's experiments to obtain a fuel most suitable for the wonderful engines designed for some of the high-speed aeroplanes. Without this high octane spirit the amazing speed attained by planes in recent years would be impossible.

In the early years of the oil age practically all the oil came from the United States or the shores of the Caspian, but now men began to bore for oil all over the world. Rumania, Trinidad, Iran, Venezuela, Canada and other countries were found to yield oil. Widespread districts were riddled with deep borings and gridironed with lines of steel pipes laid to carry the oil to the ports where it is pumped aboard "tankers." Great refining plants were built in which the crude oil is distilled. The petrol and benzine come away first.

Topical Press.

"ROUGHNECKS" WORKING AT THE DRILL

A great deal of hard and heavy work is necessary before the oil far below the earth's surface is reached. In this picture, taken during drilling operations in the Mene Grande, Venezuela, a team of heavy workers, known as "roughnecks," are seen in action They are adding a new length of pipe as the drill penetrates to a greater depth.



Topical Press.

OIL PIPES AT CURAÇAO

The largest island of the Dutch West Indies, Curaçao lies forty miles north of the Venezuelan coast. It has given its name to a well-known liqueur, but is known more to-day as a great oil distribution centre. Here we see some of the loading-pipes which run from the tanks to the piers in the refinery at Curaçao.

Then, at a higher temperature, the paraffin oil, followed by lubricating oils.

When a site is chosen for an oil-well a tall derrick is erected and boring begins. The boring tool is like a great chisel. It is enormously heavy, as it is often called upon to penetrate hard rock. These bits vary greatly in size and shape according to the type of sub-soil they have to penetrate.

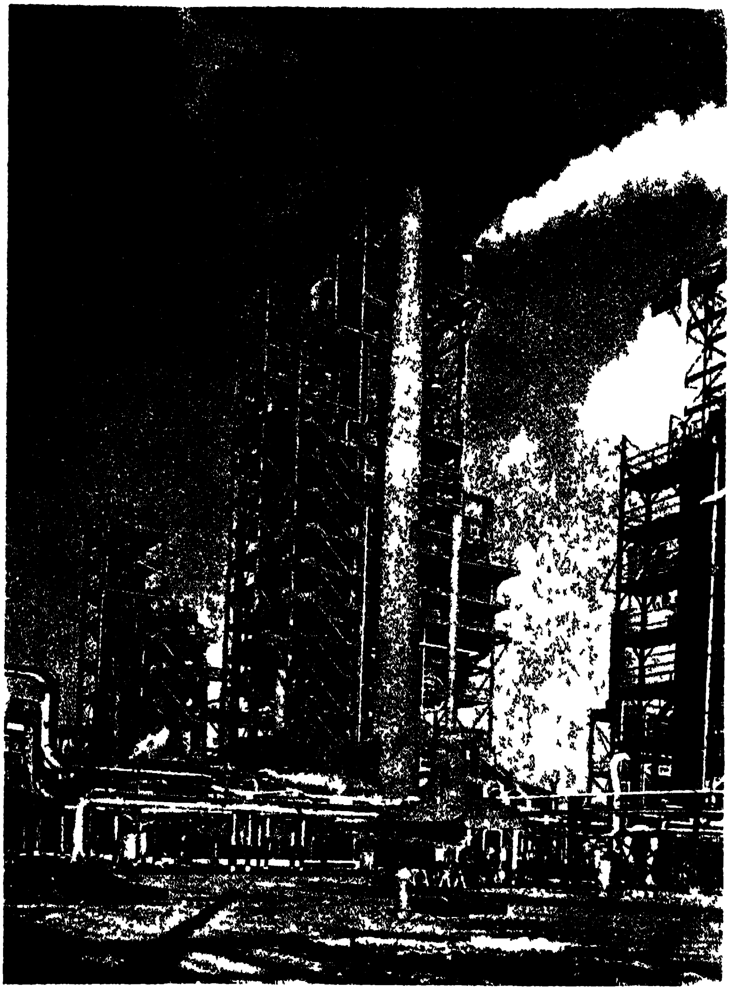
As the well is sunk metal casing is driven down to keep the sides from collapsing, and exclude water. This casing is made up of sections which are screwed on length after length. When the friction becomes too great to allow further driving, a smaller drill is used to continue the hole, which is lined with pipes fitting inside the first set.

Happily there are few dangers attached to drilling oil wells nowadays. Scientific aids of various kinds enable drilling crews to be advised of any trouble that may be expected, and, when the conduct of affairs is in the hands of an experienced oil company, such events as a well getting out of control and gushing forth a mighty jet

OIL FROM BELOW THE LAKE

Topical Press.

The South American Republic of Venezuela has now become one of the greatest oil-producing countries of the world, second only to the U.S.A. Some of the richest strikes of oil have been made in the basin of Maracaibo, west of the Andes, and wells are being sunk below the waters of the lake. Our photograph shows a member of the Venezuelan National Guard gazing out across Lake Maracaibo towards the towering derricks.



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A REFINERY FOR AERO-ENGINE OIL

The crude oil from the wells requires different treatment according to its quality and the purpose for which it is to be used. Here we see a refinery where the petrol used in high speed aero engines is prepared. This particular plant produces what is known as 100 octane spirit.

of oil high into the air are very exceptional.

Some years ago a Tartar, named Tagiet, struck oil on the shores of the Caspian, and the oil spurted out of the bore-hole at the rate of 11,000 tons a day, a quantity which it was impossible to keep under proper control.

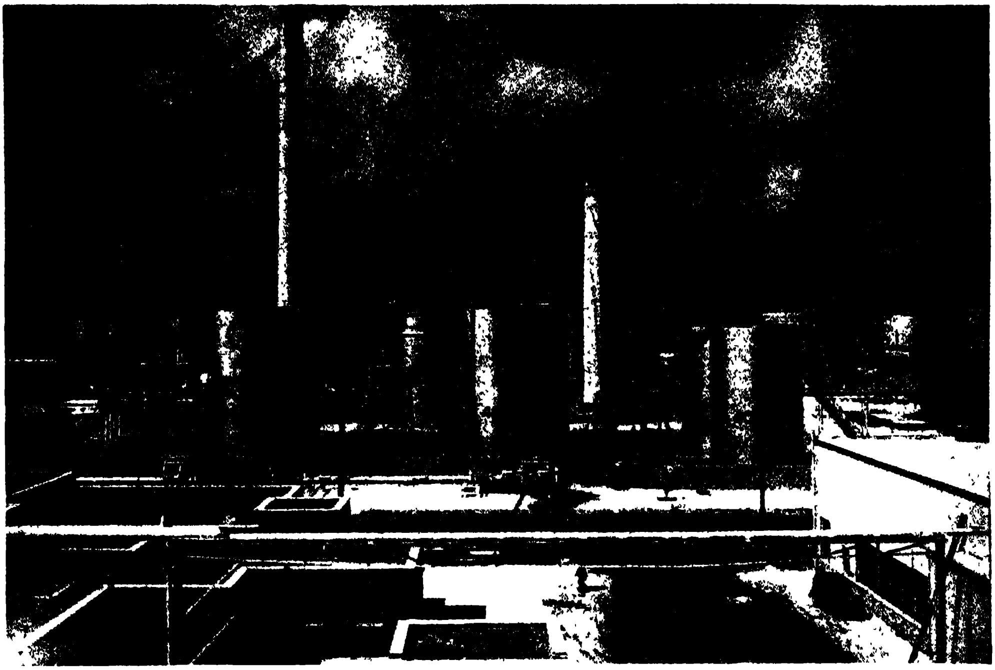
From the town of Baku, some miles away, the oil fountain looked like an immense pillar of smoke. Clouds of oil spray floated away before the wind and covered everything for a distance of eight miles to leeward. The whole countryside was flooded with oil and people fled for their lives.

"Capping" a Well

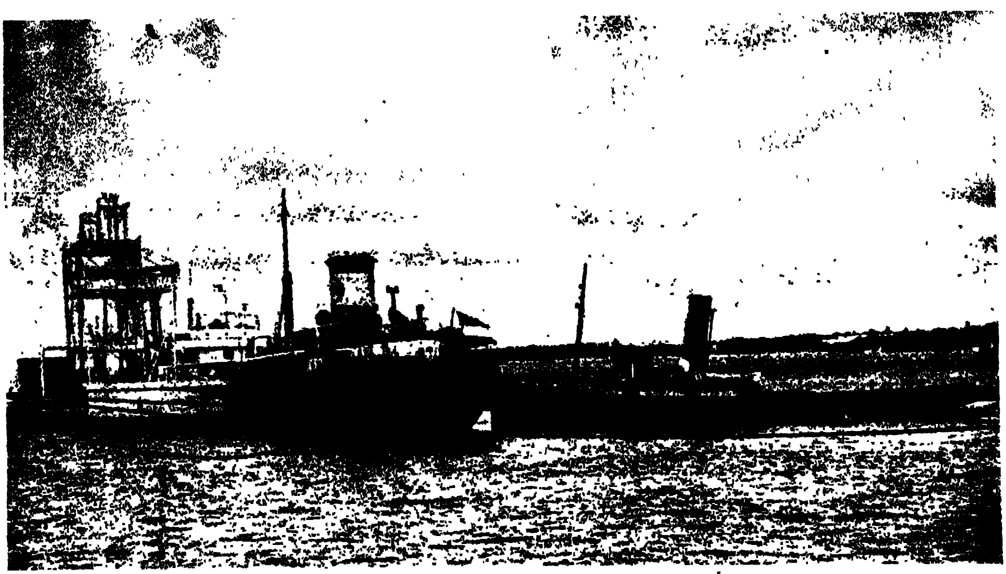
An attempt was made to "cap" the well, but the thick steel lid which was drawn over the opening was soon bored through by the sand contained in the oil. A huge mast was then obtained, weighing no fewer than 70 tons, and was driven down the bore. This checked the terror, but only for a day or two, then the mast was blown out like a shot from an air gun and the oil rose into the air to a height of 300 feet. When at last this "gusher" was got under control £1,000,000 worth of oil had been wasted.

The actual appearance of an oilfield is now greatly different from what it used to be. In former days, an oilfield was marked by a forest of huge, untidy derricks, with engines and gear on every side, and oil everywhere. To-day there is little to distinguish an oilfield from the rest of the surrounding country except for the presence here and there of a tall steel derrick, looking not unlike an ordinary electric pylon, but taller. Generally, no oil is visible anywhere, only a number of slowly oscillating pumps, looking rather like strange birds, which pump the oil from

BRITAIN'S GREATEST OIL REFINERY



At Fawley, near Southampton, a great oil refining plant was formally opened in 1951, and when finally completed will be easily the largest in Europe. Other refineries have been, or are being, built in this country, and Britain will soon be able to produce some 20 million tons of refined oil compared with 3½ million tons in 1948. At Fawley some 6½ million tons will be produced each year. In this photograph the fuel oil tanks and heaters are seen.



Photos: Topical Press.

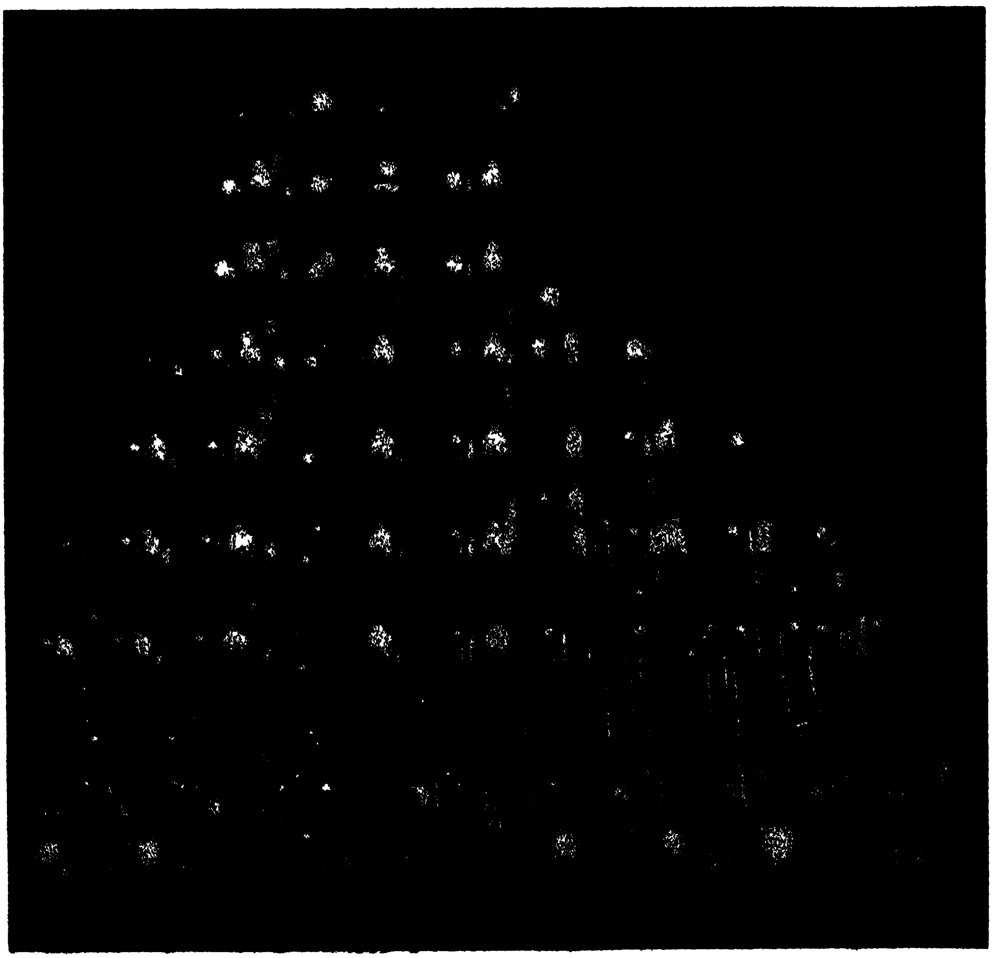
This giant plant at Fawley has splendid berthing facilities in Southampton Water, and the crude oil can be brought right to the refinery while the refined product is sent in the same way to wherever it is required. At least one large ocean tanker discharges crude oil while others are constantly leaving with the finished products. Our picture shows an Esso tanker at No. 1 berth.

a depth of many thousand feet to pass through the gathering lines to the storage tanks.

Just as coal is found in every continent and almost every country, so is oil. While coal is known to be the fossilised remains of prehistoric forests, so oil is believed to have been formed from the decomposition of vast beds of seaweed or other marine growth. Oil is now being pumped from wells driven in the sea bottom off the Californian coast, and it is certain that there are huge supplies of this valuable fluid under the Gulf of Mexico.

Up to now, the country that has produced the largest quantities of oil is the U.S.A. For many years her output has amounted to more than 60 per cent. of the world total. But as her own consumption has increased, the amount of oil available for export has diminished. As a result, other countries have now to draw their supplies from elsewhere, chiefly Venezuela, Saudi Arabia, Kuwait, and the East Indies.

The situation to-day is that everybody is consuming more oil, especially in the U.S.A. As the output in the U.S.A. may be expected to decline

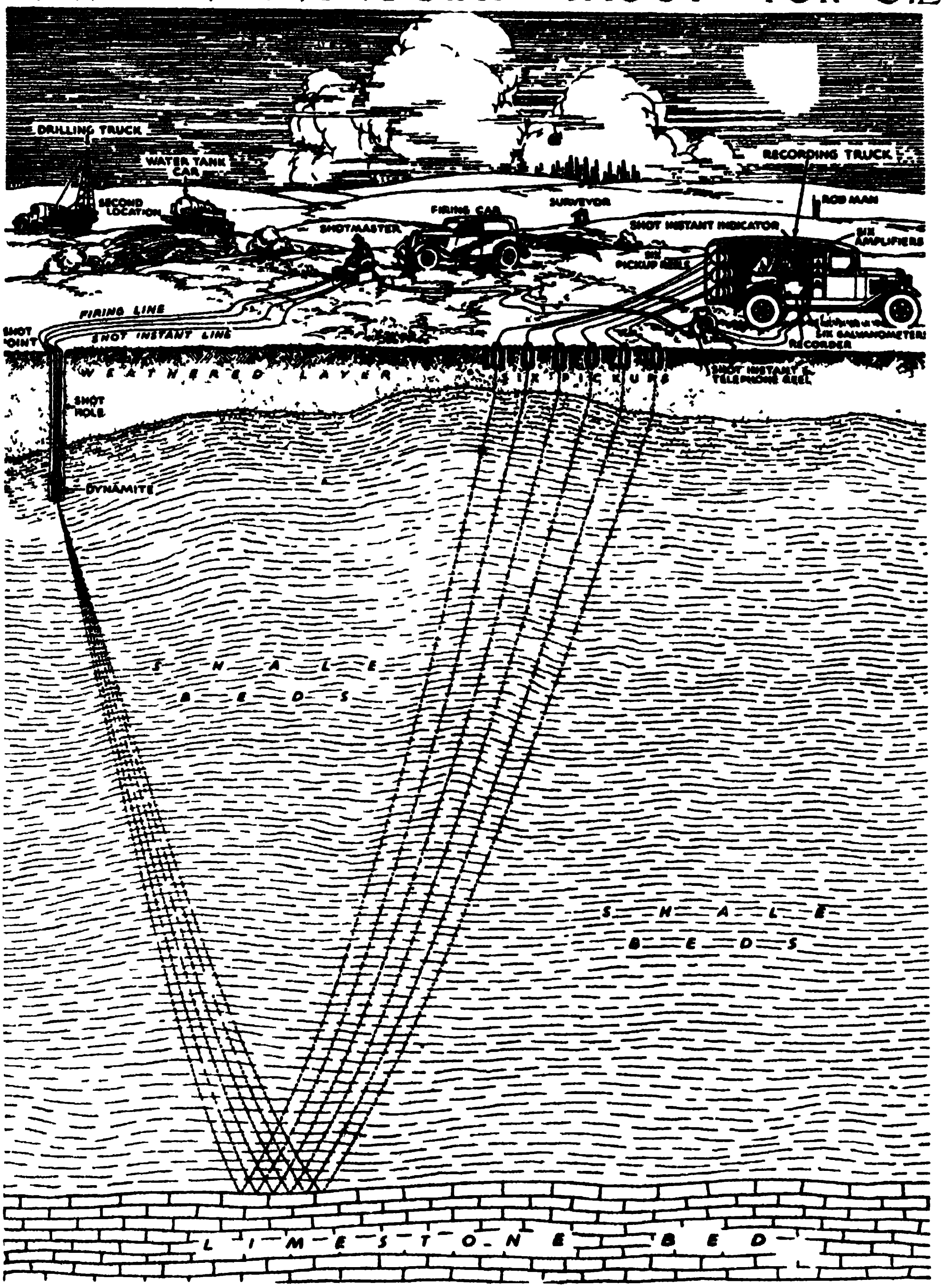


Topical Press.

AT ONE OF CURAÇAO'S REFINERIES

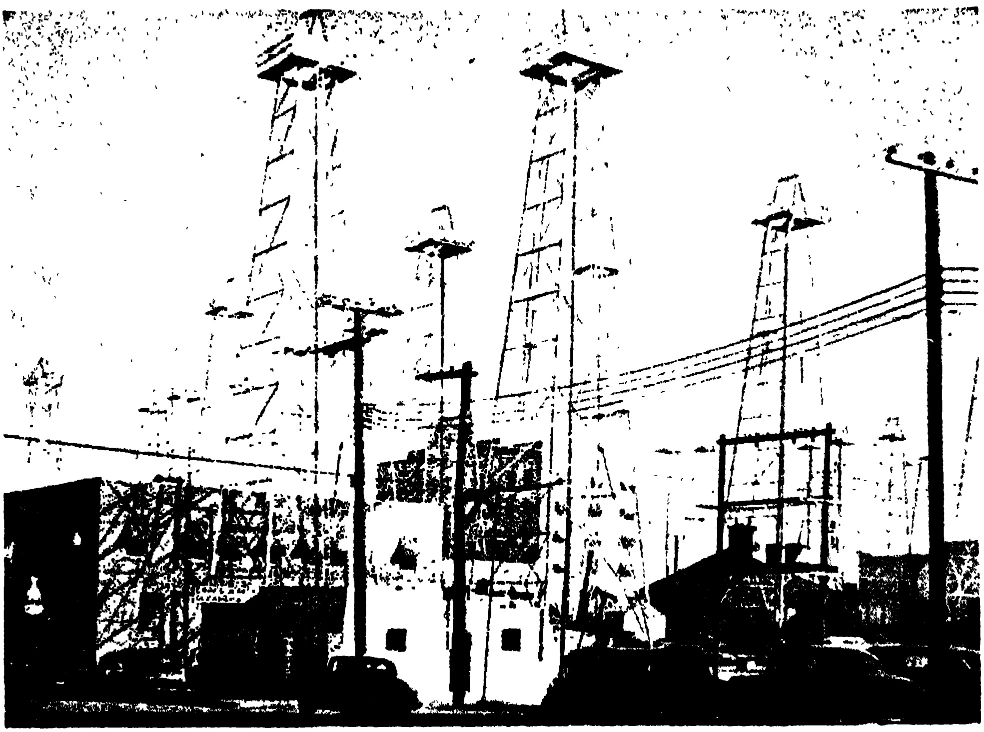
Concessions to work the oilfields of Venezuela have been granted to British and American Companies. A certain amount of the oil must be refined in Venezuela itself, while other refineries have been established on adjacent islands. Here we see the alkylation plant at a Curaçao refinery.

HOW THE GEOLOGISTS "SHOOT" FOR OIL



Shell

A certain amount of intelligent guesswork has to be done by the geologists who assist the oil prospectors. Various tests are employed and the diagram above shows what is known as the seismic method. Into a bore hole, not more than 100 feet deep, an explosive such as gelignite is placed and then fired. The result is a small earthquake, sound waves from which are received in the recording van. The record tells the experts the exact nature of the ground far below and whether oil is likely to be found.



Pictorial Press.

AS SEEN IN A TEXAS OIL TOWN

Up to the present the U.S.A. has produced the largest quantities of oil, but there is a possibility that supplies from this country may decline in the years to come. Our photograph shows a downtown section of Kilgore, Texas, studded with oil derricks, and gives some idea of what a modern oil town is like.

gradually, she may have to look elsewhere for part of her supplies. This is the reason why so much attention is being paid to-day to the Middle East as a source of supply. It contains the largest reserves in the world so far as is known at present.

Prophecies regarding oil supplies must always be mixed with caution. The United States authorities, while looking elsewhere for oil supplies in case their own wells run out, have not relaxed efforts in their own country. In March, 1948, for instance, it was officially announced that an oil shale deposit in Colorado was being developed and that this new source was believed to have a potential output of about ten times the volume of all oil so far drilled in the U.S.A.

It is possible, so the experts believe, that this may become the largest mining operation in the world. The method employed in the case of this deposit is to mine the shale rock and transform the nearly solid petroleum contents into crude oil. Such a source of supply, when fully developed, might solve all the American problems of an adequate oil supply for many years to come.

In Canada, too, the production of oil is increasing. Alberta's oilfields are being steadily developed, and the Athabaska tar sands are believed to contain one of the largest known supplies of oil in the world. The development of these deposits holds tremendous possibilities. Large reserves are also known to exist in South America and intensive exploration and development work is being carried out there.

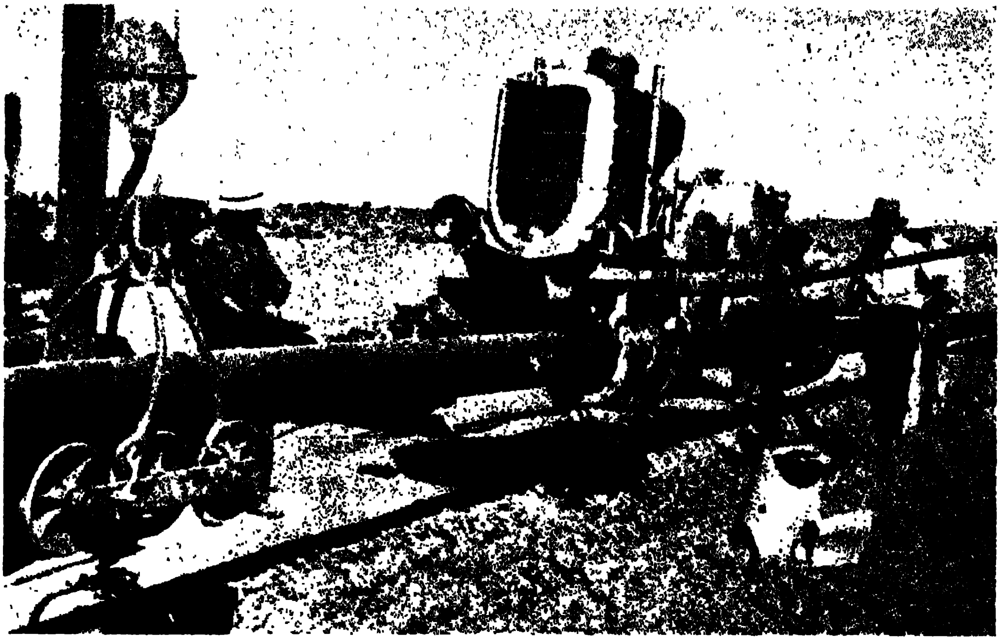
Home-produced Oil

Great Britain normally needs some

THE DRILLING CREW AT WORK

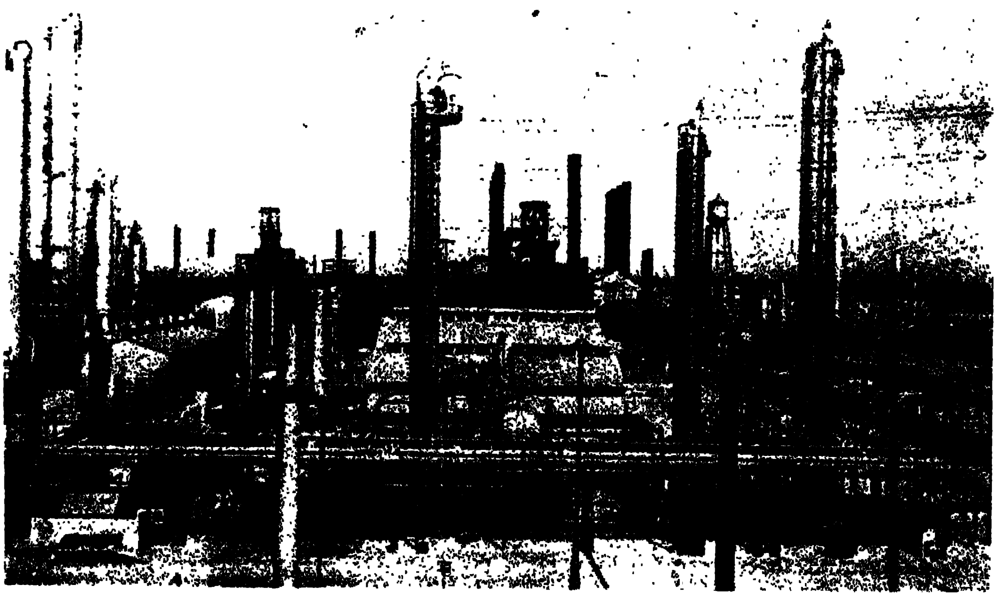
Oil is not found in pools or lakes below ground, but is always absorbed in sand or sandstone, which hold the oil as a sponge holds water. This sand or rock may be anything from 60 to 70 feet to nearly three miles below ground. To reach it a hole has to be drilled, and here we see a drilling crew at work, fixing the tackle which will drive the hole, no more than 8 or 10 inches across right down to the oil soaked sand or rock from which it will later be pumped

CONSTRUCTING A PIPELINE



Shell.

In various countries huge pipelines have been constructed to bring the oil from the place where it is found to some port where it can be conveniently taken aboard a tanker for transport to wherever it may be required. In this picture we see part of one of these long pipelines during construction. The curious-looking engine is a pipe-cleaning machine in action.



Shell.

Here we have another view of a big oil-refining plant. This photograph shows the Dominguez Refinery of the Shell Company in California, U.S.A., where Iso-octane is manufactured to form the basis of 100-octane aviation spirit.

A TANKER WITH OIL FROM VENEZUELA

The big oil companies have their own fleets of specially-constructed vessels to bring the oil from overseas to the countries where it is needed. Our photograph shows one of the Shell Company's fleet of tankers. It is carrying a cargo of oil from Venezuela to a British port.

3,000 million gallons of oil every year and could no doubt use very much more if supplies were unlimited. Practically all this quantity has to be brought to our shores in the specially-built oil-carrying ships known as tankers. Everywhere the demand for oil is increasing and in recent years motorists in this country, and in others, have had to endure severe restrictions simply because this ever-increasing demand for petrol cannot, for various reasons, be adequately met.

Oil has been discovered in Britain but the prospect of obtaining sufficient supplies for our needs at home is highly remote. In 1911 an experimental boring was made in Nottinghamshire and in 1918 the first real oil-well was drilled in Derbyshire. The experts continued their search and by 1945 there were some 240 wells in this country, mainly in Nottinghamshire and Lancashire. Over 25 million gallons of petrol were produced in a year, but this is not a hundredth part of the total amount we require.

A certain amount of petrol is being made from coal in England, but the supply is limited. In Scotland a particular substance known as oil-shale was dug from the ground years ago and a certain amount of oil extracted from it. When large quantities of petrol were easily imported from America no one troubled very much about shale-oil. To-day with new methods of extraction the shale-oil industry is being developed. The shale is dug from comparatively shallow mines in much the same way that coal is mined; later the shale is treated in retorts and various products extracted during the process of distilling, condensing and refining.

We speak of petroleum as a "mineral oil," and not only does it give us petrol, paraffin and fuel oil for steamers, locomotives and different kinds of

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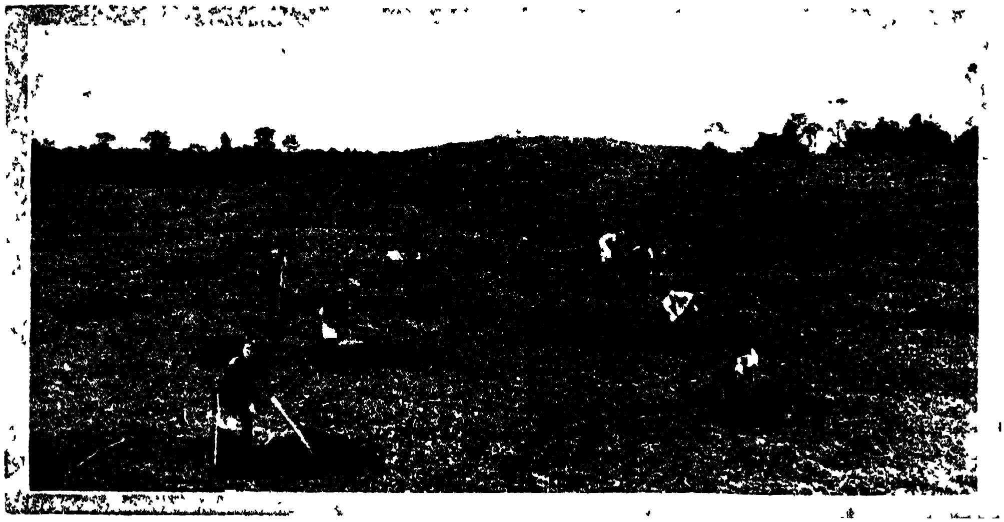
UNLOADING OIL AT A BRITISH PORT

In modern times great pipelines have been laid from the oilfields to the ports where the tankers take it aboard through flexible pipes, wire-covered to safeguard them against injury. After its journey in the tanker across the seas, the oil is unloaded, and in this photograph is seen a tanker at a British port. The oil pipe-line from the shore is being lowered by a crane in readiness for the task of taking the cargo of oil ashore.

heavy engine, but it also affords paraffin wax, from which candles are made.

Vegetable oils come from seeds, nuts and such sources; animal oils from fish and the fats of many other creatures.

THE EVER-USEFUL RUBBER



Rubber Growers' Association

MAKING A RUBBER PLANTATION

A short time ago this land was covered with jungle It has now been cleared, and coolies are planting it with rows of evenly-spaced young rubber trees from the estate nurseries These plants have been reduced to stumps, but they will send out shoots and grow into sturdy trees

ABOUT the year 1500 the Spanish adventurers who were conquering Mexico brought home to Spain some small, hard, black balls which *bounced* in a way which was new to all beholders. They were made, so the travellers said, from the black resin of a tree, called by the natives "Ulaquahuil."

This was the first rubber seen in Europe. It was looked upon merely as a curiosity, and it was a great many years before it was thought of as anything else. Priestley, the great English chemist, found that it was good for rubbing out pencil marks, and that is how it got its name "india-rubber." That was about the year 1770, but another seventy years had to pass before it was discovered how to *vulcanise* india-rubber.

Rubber is a peculiar commodity. It will not dissolve, like so many vegetable saps, in water or alcohol. It was discovered, however, that by heating it with sulphur, it could be handled quite easily. It became more elastic, was not hardened by cold or softened by ordinary heat, and it could be made into thin sheets which, when applied to cloth, made the cloth waterproof.

It could also be made into "vulcanite," the hard form of rubber which is good for making combs, penholders, buttons, paper-knives, etc, Vulcanite can be moulded or carved into a hundred forms, and one of its advantages is that it is a *non-conductor* of electricity.

From the Amazon Valley

So began the use of india-rubber For the first time in history men had overcoats through which no rain could penetrate; goloshes, shoes which were impervious to wet; garden-hose which could be coiled up and made of any length desired; belting for machinery better than any yet made; and, as time went on and motor cars came in, air-filled tyres on which these swift vehicles could speed at paces up to six miles a minute.

Several different trees supply the "latex," or sap, from which india-rubber is made, but the most important is the *Hevea brasiliensis*, which is a native of the Amazon valley. For many years Brazil was the sole source

MILKING A RUBBER TREE

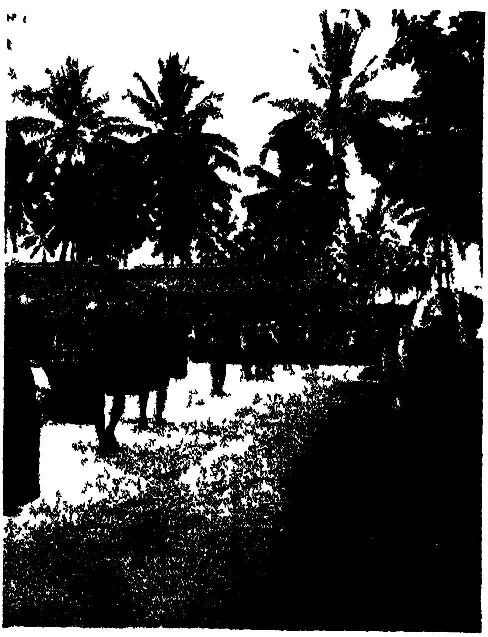
Topical Press

This method of "tapping" a rubber tree is called the herring-bone system. Sloping grooves are cut in the bark of the tree on both sides of a central vertical channel, which leads the exuding latex or milky juice down into a collecting cup at the bottom. The coolie in charge of a section makes his rounds periodically and empties the latex from the collecting cups into his pail.

A RUBBER PLANTATION IN MALAY

Here we see the rubber seedling trees growing in the nursery beds of a plantation near Kuala Lumpur, Malay. The weeds are kept down by Indian coolies

Another method of tapping the rubber trees by removing a small section of the bark in a full spiral. The latex appears at once and drips into a small cup hanging on the wire below



In this picture the tappers are returning with their pails of latex after the morning's work on the plantation. Most of them have two buckets carried in milkmaid fashion

Photos Topical Press

Inside the plantation factory, the latex is mixed with formic acid then passed through rolling mills to make into sheets. These sheets are then hung out to dry

ROLLING AND DRYING

The blocks of coagulated rubber are here being rolled out like pastry and then passed through rollers while being washed to flatten them further into thin sheets of crepe rubber Various methods of rolling are used, to produce different kinds of crepe and sheet in which forms raw rubber is sold to manufacturers of rubber articles

Photos Rubber Growers' Association.

Crepe rubber hung up on racks in a drying house What is called 'pale crepe' is dried by a natural draught of air circulating among the sheets, while smoked sheet is exposed to the smoke from wood fires burning on the ground below The smoking gives the rubber a dark reddish-brown colour

BRINGING RUBBER TO MARKET

The sheets of cured rubber are carefully sorted, weighed, folded, and packed into strong ply-wood cases, each containing from 1½ to 2 hundredweights of rubber. In this picture coolies are seen carrying cases from a native craft called a wallam into a storehouse, where they will remain until required for shipment.

Photos: Rubber Growers' Association.

The scene is now shifted from the East to a warehouse in London. The raw rubber is here being unpacked, weighed, sampled and got ready for inspection by buyers. London is one of the greatest rubber markets of the world. Well over 150,000 tons of rubber enter London docks in a year.

of the world's rubber, and great fortunes were gained by tapping the wild trees.

Terrible work it was, and is, in those steaming tropical forests which reek of fever and pestilence. For hours daily the rubber gatherers work in swamps where they sink over their ankles, amid rivers swarming with alligators, surrounded by poisonous snakes and clouds of stinging insects, threatened by all kinds of disease, especially that terrible one called "espundia." For the wild rubber tree attains greatest perfection in conditions that are most terrible for human beings.

The Smuggling of the Seeds

This sort of thing could not go on, and in 1876 it was decided to endeavour to transplant the rubber tree to India Mr. Henry Wickham was entrusted with the task of collecting seeds from Brazil by the authorities at Kew. Now, the Brazilian Government, well aware of the value of rubber, had made laws against allowing any of the seed to leave the country, and Mr. Wickham did not know how to get past the Customs' examiners.

Dunlop Rubber Co., Ltd

RUBBER FOR CAR TYRES

A wide band of unvulcanised rubber being passed between huge rollers and slit down the middle into two parts, each of which will be cut up into lengths for covering walls and treads

Chance came to his help. While far up the Amazon he was surprised by the arrival of a large steamship, the S.S. *Amazonas*, which had been sent from England to trade up the Amazon. She could find no cargo, however, and was on the point of being abandoned when Wickham chartered her on behalf of the Government of India. With great secrecy he got a quantity of rubber seeds aboard and hid them. Then he sailed for home. Somehow he managed to evade the officials at the river mouth, though this was not easy, because the only ***navigable*** mouth of the Amazon is very narrow—the big mouth you see on the map is shallow and full of sand banks. Eventually he delivered his seeds at Kew, where they were germinated in hot-houses For this great service Mr. Wickham was afterwards knighted.

Sent to India

The young plants were, in due time, sent to India in "Wardian" cases, like small portable greenhouses, and set out in botanical gardens in Ceylon, Singapore and elsewhere. Here, it is now difficult to believe, no one would bother to grow them. Planters were all too busy with tea and coffee. Then came the coffee-leaf disease, which destroyed all the trees in Ceylon and forced growers to look for some other crop. They started rubber, and to-day most of the world's rubber comes from countries of the East. The Malaya plantations produce 700,000 tons a year, nearly half the total natural production.

A rubber tree is first tapped when five or six years old. The bark is pared away, a bit at a time, to expose the tubes in which the milky, rubber-yielding latex collects. The "milk" drops into a cup, and the contents of

Specially painted for this work

TAPPING A RUBBER TREE

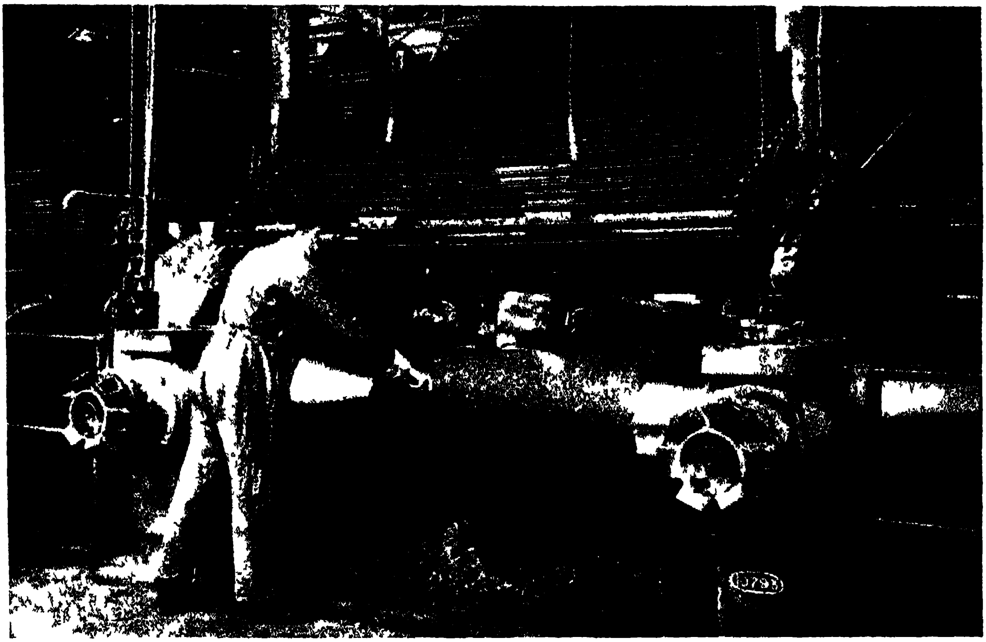
Extracting the rubber-bearing latex or milky juice from the bark of a rubber tree is done very systematically in order to maintain a constant supply without damaging the tree. The cut in the bark, as shown in the picture, began with a groove made just below the tapper's left hand and reached one third of the way round the tree. It will be extended downwards to within a foot or so of the ground. Then the other two thirds will be tapped successively in like manner. By the time the third cut is completed the bark in the first will have renewed itself.

Specially painted for this work

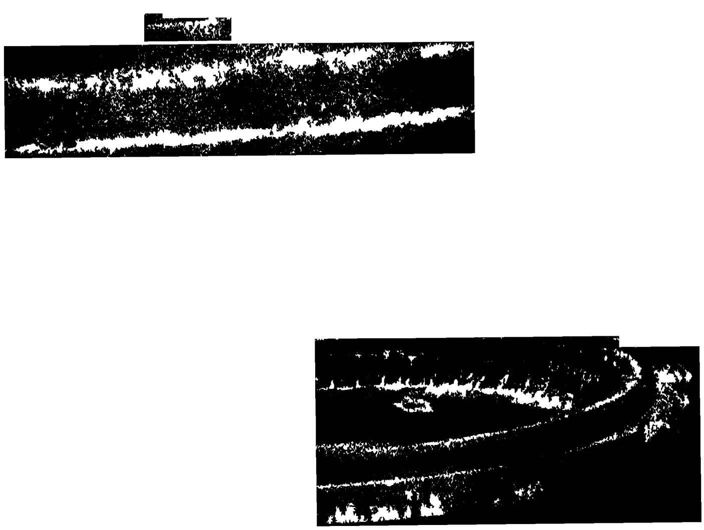
COTTON GATHERING IN EGYPT

Cotton grown in Egypt ranks among the best in the world because the climate and soil admirably suit the needs of this invaluable plant. We see above the gathering in of the harvest by girls and boys. Most of the work, such as seed sowing, thinning out seedlings and hoeing, is still carried out by hand. Channels are cut to bring water from the Nile to thirsty roots, and it should be noted that gatherers wear special aprons in which to collect the seed heads. Camels convey the crop to warehouses where the cotton is baled ready for shipment.

TWO STAGES IN TYRE MANUFACTURE



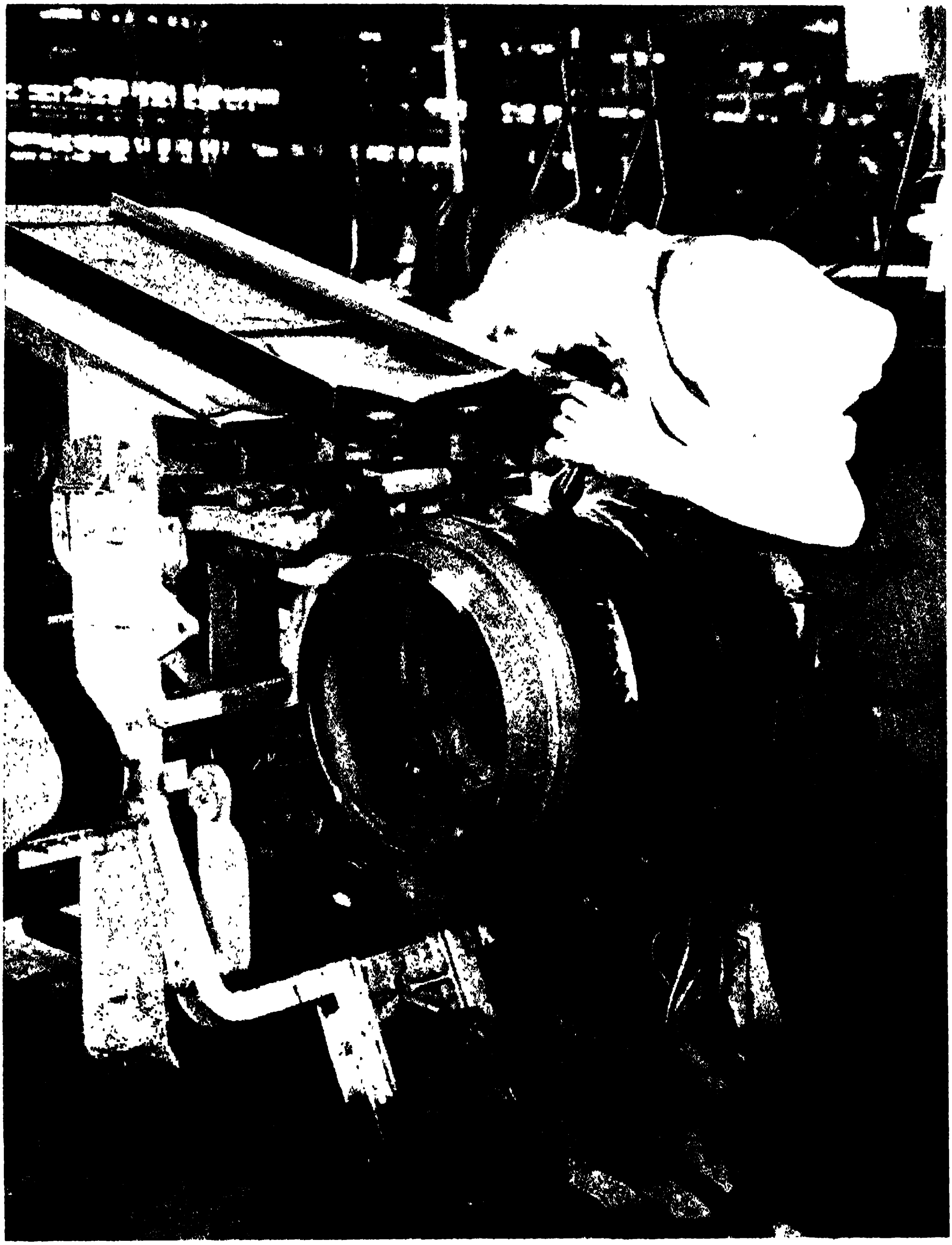
In this picture we see the raw rubber as it is received in this country, being " masticated " at the works It is passed between heated steel rollers to make it fit for the next stage.



Dunlop Rubber Co, Ltd.

This shows a later stage in the manufacture of a heavy truck tyre A newly-built tyre is being lowered into the mould ready for vulcanisation

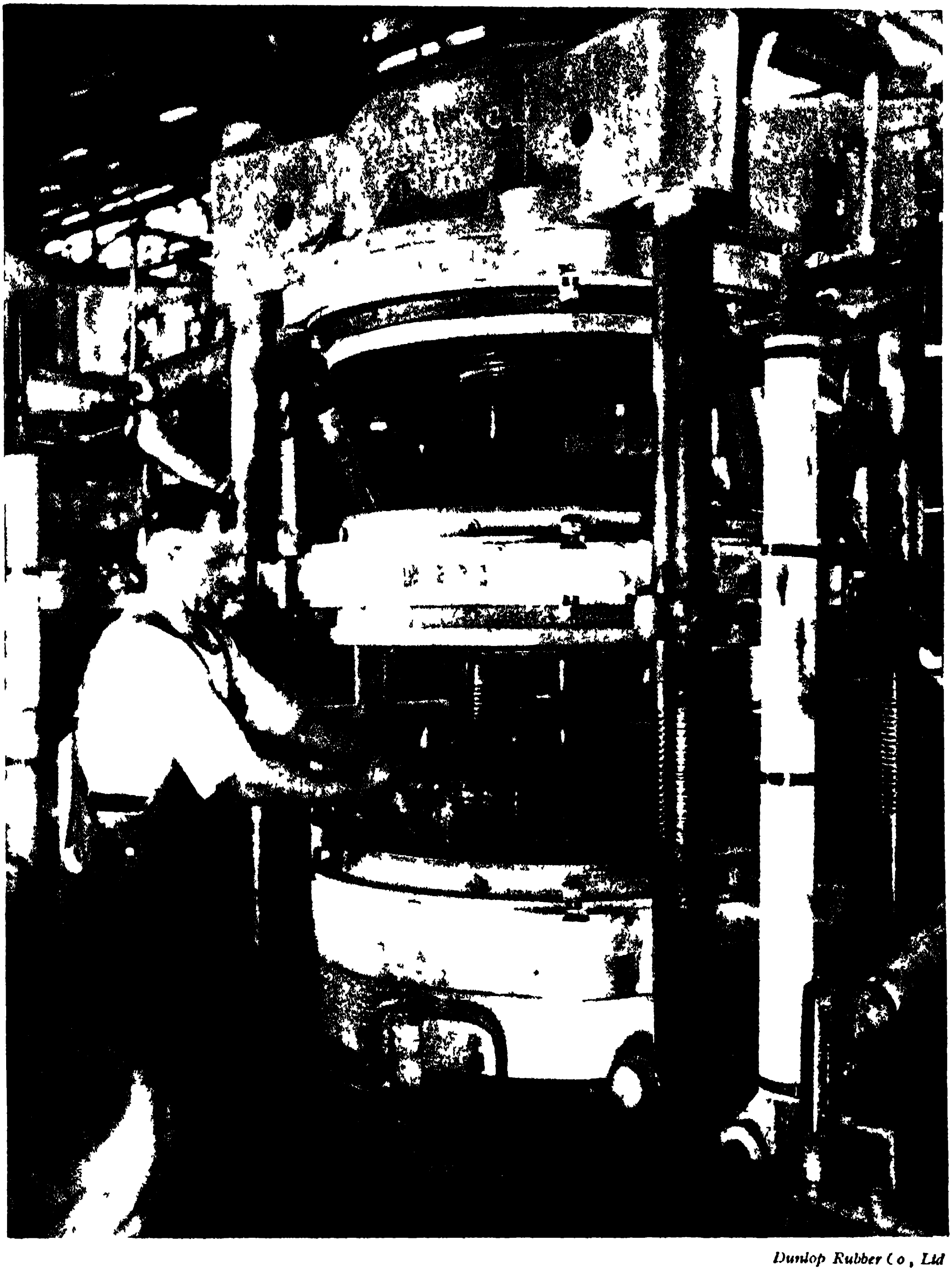
LAYING THE TREAD



Dunlop Rubber Co., Ltd.

Here we see another of the various stages in making a motor car tyre. The tread rubber and the sidewalls are being laid on a flat collapsible " Forma " on to which the rubber-impregnated cotton casing has previously been laid.

TAKING OUT A VULCANISED TYRE



Dunlop Rubber Co, Ltd

On a previous page we saw the tyre being lowered into the mould for vulcanisation In this picture the great press is seen more fully as the freshly vulcanised tyre is removed from the mould In the vulcanisation process sulphur is added to the rubber

these cups are emptied into pails, which, in turn, are emptied into tanks. The fluid is later coagulated (made firm) by adding a little formic acid, and is then washed and rolled into sheets, which take on a pale yellow colour. Sometimes the sheets are smoked and are then known as "smoked sheet."

The sheets are shipped to Europe or America for making up into various objects, from elastic bands to great motor tyres. Vulcanising, which used to be a slow process, is much hastened nowadays by mixing with the rubber certain chemicals called "accelerators."

The Value of Rubber

The cycle and the motor car could not exist without rubber tyres, while football, tennis and golf would be equally impossible without rubber to make balls used in these and other similar games. Electrical engineering depends largely on rubber, and so does the medical profession. Rubber gloves, rubber sheeting, rubber tubing for administering anæsthetics, rubber castors for operating tables, rubber mattresses—these are only a few of the many uses of rubber in modern medicine.

For Paving Roads

In the home we have rubber hot-water bottles, rubber sponge bags, rubber bath mats, and many other rubber-made articles. Rubber soles our shoes and is rapidly replacing leather for that purpose. In the office you find rubber erasers, rubber stamps, rubber bands and rubber pencil holders. Nearly all fountain pens are made of vulcanite. When rubber was plentiful we began to pave our roads with it. Rubber is in truth one of the most useful substances known to man.

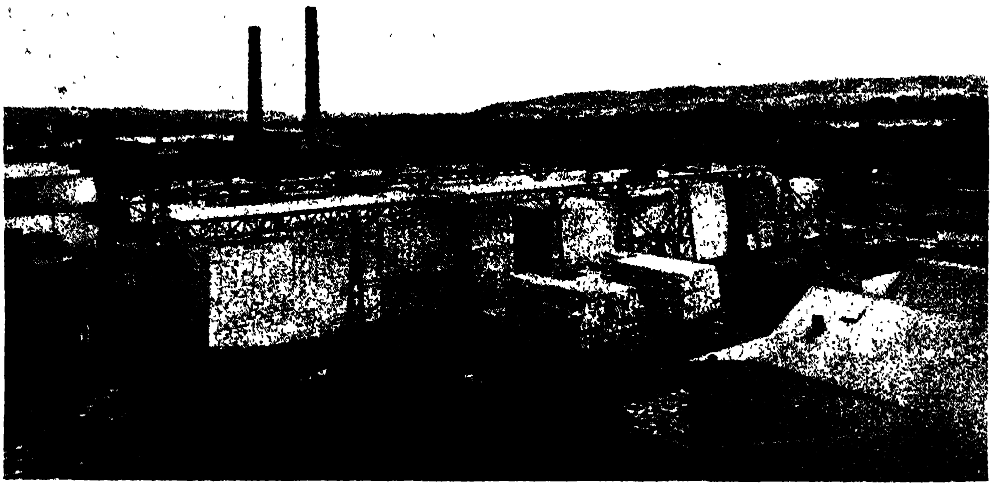
One may start a rubber plantation from seeds, but a quicker method is to plant trees. These are cut down and trimmed to mere stumps but develop quickly and grow into strong trees.

Dunlop Rubber Co., Ltd.

A BATTERY OF TYRE-BUILDING MACHINES

Many thousands of tyres are required each year for motor vehicles of all types as well as cycles and other road carriages This picture shows the scene in a factory at Fort Dunlop where a battery of tyre-building machines is in operation

HOW PAPER IS MADE



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From about 1873 onwards, wood pulp has been used more and more for the making of paper. In this picture are seen the great stacks of baled wood pulp as it looks when brought to this country from overseas. In the forest regions where the cone-bearing trees flourish, the wood is chopped up and made into pulp by means of chemicals. This pulp is dried and shipped to the papermakers overseas.

PAPER is one of the world's oldest inventions. The Chinese, who usually claim most of the big inventions, certainly made paper hundreds of years before the time of Christ, but it is doubtful if they were ahead of the ancient Egyptians, who manufactured papyrus paper out of reeds fully 4,000 years ago. They cut the pith out of the reed called papyrus, laid the thin slices side by side, moistened them with water, rolled them flat and polished them with an elephant's tusk.

The Chinese formed their first paper out of mulberry trees and sprouts of bamboo, and later discovered a way of pulping silk waste and turning it into paper. Tsai Lun, a Chinese inventor, who lived about 100 years after Christ, found out how to make paper of bark, hemp, rags, and even from worn-out fishing-nets. Chinese artisans crossed Asia and took the invention to Samarkand, where paper-mills were erected more than 1,000 years ago.

The Arabs made paper of rags, and the Moors brought the invention to Spain. At last, in or about the year 1460, the first paper-mill was established in England, and in 1590 the mills at Dartford were started. Since then Britain has become one of the greatest paper-makers and users in the world, and in 1889 an English maker showed in Paris paper made from sixty different materials.

Pulp for Paper

Almost any vegetable growth has a fibrous structure or framework which can be converted into paper. To be of any use to paper manufacturers, however, it must be cheap and in plentiful supply. For centuries nearly all our paper was made from cotton and linen rags, but as the demand for paper increased the supply of rags became totally inadequate. About 1850 experiments were made in making paper from Esparto grass, a very long, thin, wiry grass that grows in the swampy areas of North Africa. Esparto

grass proved highly suitable as it contained a very good proportion of fibre, and within thirty years we were importing about 220,000 tons yearly. To-day it is largely used in the manufacture of good quality paper for books and other better class publications.

In 1873 wood pulp was first introduced for paper-making, and by degrees was found to be by far the cheapest and most satisfactory material for that purpose, so that nowadays nearly all paper, except the best note, is made from wood. But all woods will not do for paper-making. Oak, ash and beech are practically useless for the purpose. The fibre is not long enough. Only the wood of certain cone-bearing trees is suitable, and, in point of fact, most of our paper-making material comes from Scandinavia, Newfoundland and Canada.

Wood to be used for paper-making is first chopped up and sliced by machinery, then pulped with chemicals, such as caustic soda and sulphurous acid, in vats heated to a high temperature. To save cost of carriage, this is usually done at works close to, or connected with, the saw-mill, and the pulp, not the timber, brought across the sea.

Making the Paper

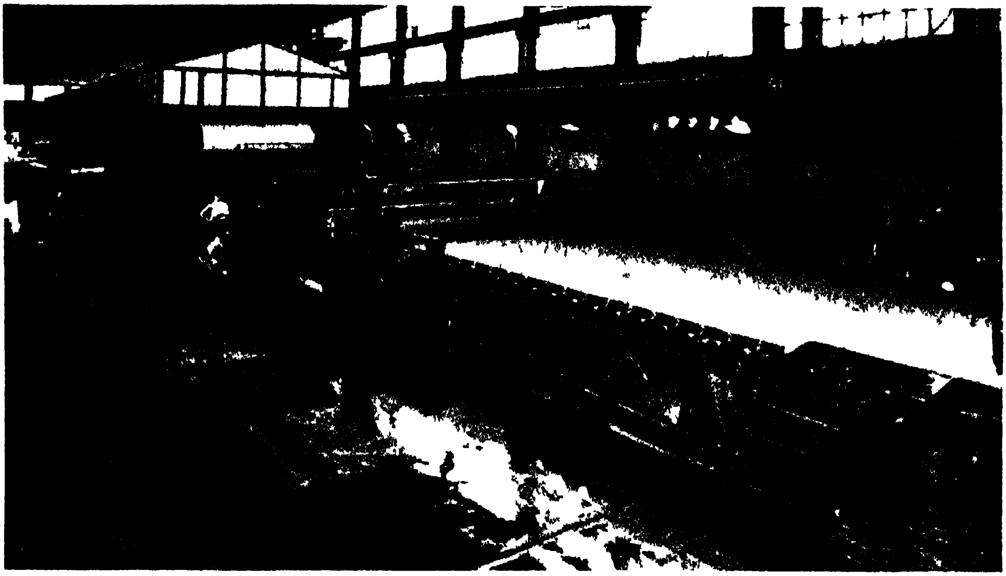
The pulp has to be carefully bleached before it can be used. It is then mixed with water to about the consistency of cream, and this pulp is run out on to a table made of wire cloth. On this wire cloth the pulp is carried along and strained and dried as it goes. It passes between rollers, which squeeze out the remaining water, and after this looks like very thick, rough blotting-paper. It is then called "half-stuff."

Copyright.

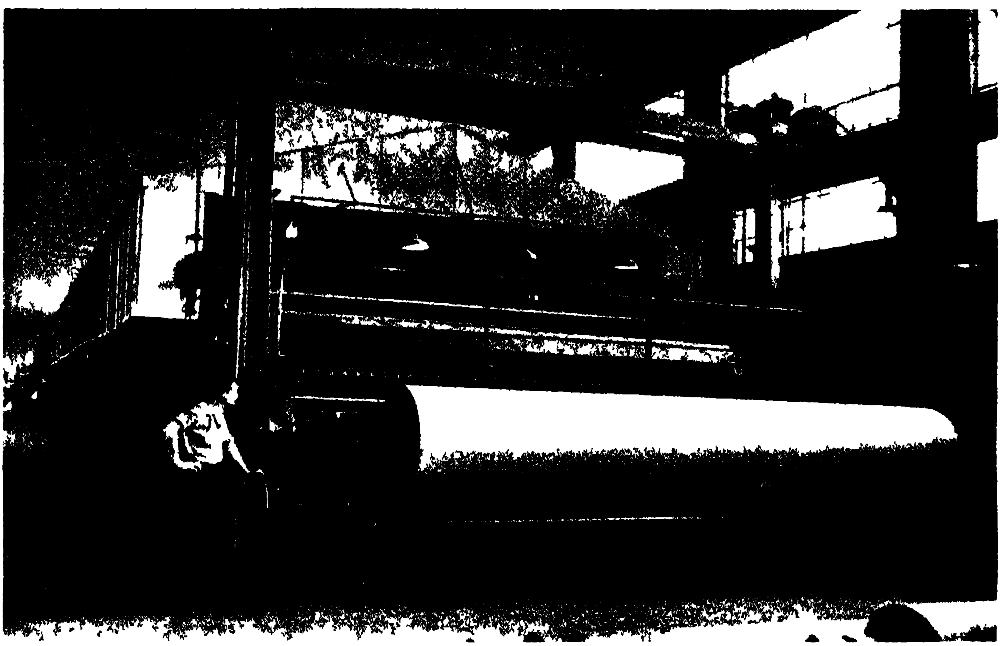
THE FIRST PROCESS AT THE MILL

Wood pulp in its natural state is a greyish, dirty hue, and altogether too lumpy. The first task at the mill is to break up this raw material by a process of beating in great tanks, as seen above. In these tanks certain chemicals have been mixed with the water and these chemicals are absorbed by the pulp and act as a bleaching agent to give the necessary whiteness.

MAKING PAPER BY THE MILE



In the two pictures on this page the machine which really makes the paper is shown. The material starts at the "wet end" as a creamy liquid stream. It is carried forward on an endless wire cloth through which the water drains assisted by suction boxes. The fibrous film then travels round steam-heated cylinders and rollers that drive off the rest of the water and make the sheet firm.



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Eventually the material which began as the creamy pulp arrives at the other end of its long journey through the machine, which, as can be seen above, is of truly tremendous length. This photograph shows the "dry end," and the paper comes steadily forth to be wound on the great reel.

Copyright.

We are all familiar with the process of ironing starched material such as collars and cuffs so that a perfectly smooth, shiny surface is produced. The big rolls of paper seen in the picture above are going through a very similar process. The heated rollers press the paper and dry it, giving to the paper what is known as a " calendered " surface, smooth and shiny.

This is broken up again with a quantity of pure water, dried and rolled out afresh.

It is during this second process that any necessary colouring matter is added as well as the " filling " or " loading." China clay or calcium sulphate is used for filling, and makes the paper more solid. " Size " is also added. The last process is to run the sheets between smoothing rolls and polished rollers of chilled iron, which give it a smooth surface.

The pulp made in this way is known as chemical wood ; it is of good quality and will retain its colour for a long time.

Pulp for Newspapers

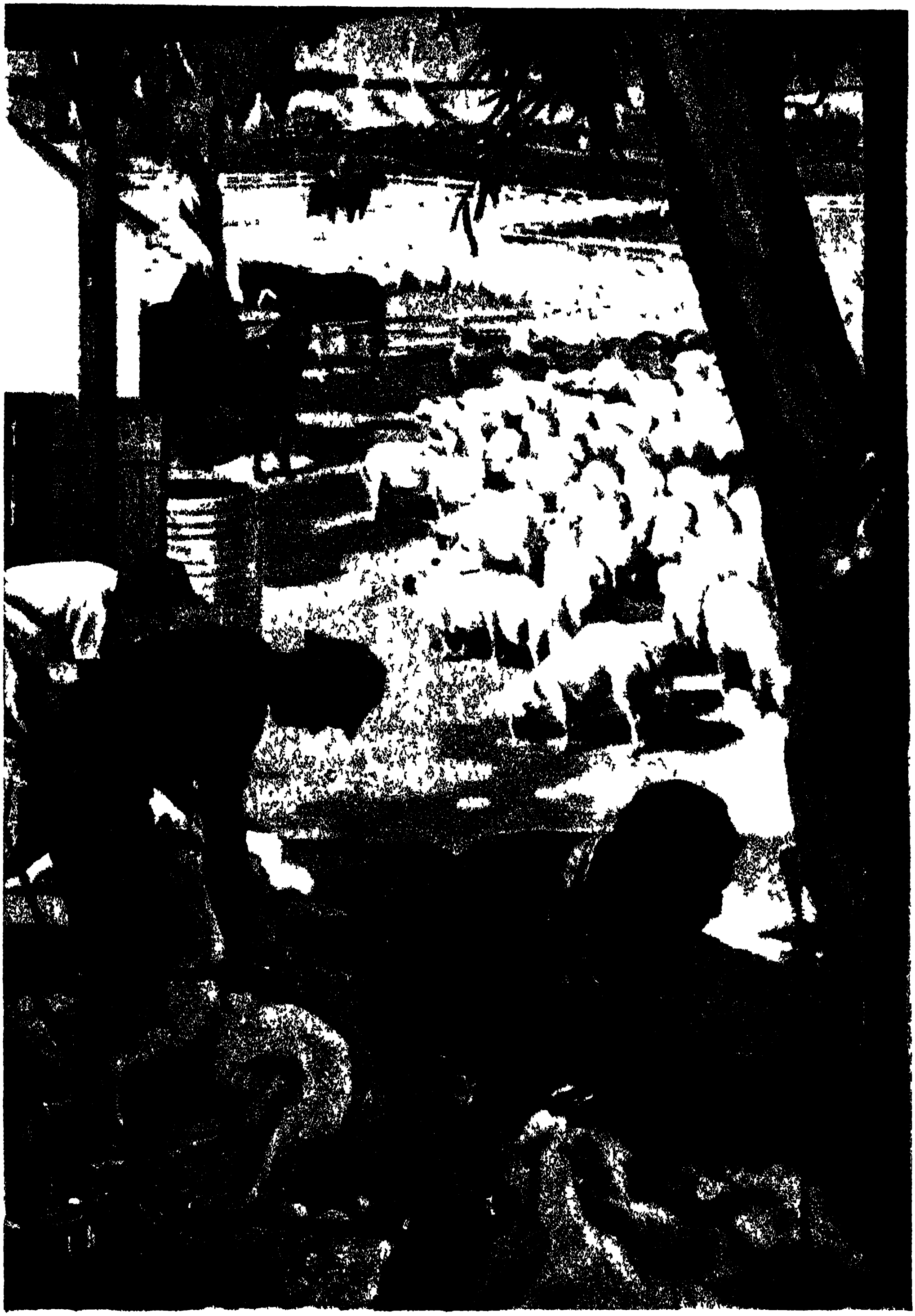
In the case of newspapers it is not so important to use a paper of good quality as the daily papers are usually bought, read, and then thrown away. For newsprint an even cheaper and quicker process is employed, producing what is known as mechanical wood pulp because it is made by the mechanical process of grinding logs of wood on revolving wet grindstones. Many millions of tons are made in this way every year.

Pulp made in this way is practically a fine sawdust, with torn fibres that are too short to use entirely alone. This pulp is therefore mixed with chemical wood pulp ; approximately one part of chemical pulp is mixed with four parts of mechanical, and the longer chemical fibres give the necessary strength to make the finished sheet hold together. Paper made from this mixture is known as " newsprint," and the machines making newsprint have gradually become larger and increased the speed at which they run. One machine in Britain makes a sheet 300 inches wide at the rate of 1,250 feet per minute.

This is only a very brief description. A glance at our pictures of paper-making machinery will give a better idea of the many processes through

COSTUMES THROUGH THE CENTURIES

The manufacture of woollen cloth for wearing apparel is one of Britain's oldest industries, and today both woollen and cotton goods are among our most important exports. In this picture we have a pageant of the dress worn in this country at different periods. It will be seen that until comparatively recent times men as well as women favoured brightly coloured costumes. Trunk hose, reaching from foot to thigh, was succeeded by breeches, and it was not until the nineteenth century that trousers became the fashion. For women the long skirt persisted until modern times.



Specially painted for this work

SHEEP-SHEARING IN AUSTRALIA

Wool is a valuable commodity because it enables us to endure the cold of our northern winters. Though we still produce much wool at home the immense flocks of sheep in Australia and New Zealand now yield about one fourth of the world's supply much of which finds its way to the mills of Yorkshire. Our picture shows mechanical shearing on an Australian sheep station.

which the pulp passes before it comes out, ready to be cut into sheets for printing newspapers or books

Made from Rags

The best sorts of notepaper, and paper for special illustrated books, is made of linen and cotton rags, which are first freed from dust, then carefully sorted and cut up by a machine. They are next boiled in caustic soda, and a solution of bleaching powder (chloride of lime) is added, in which they soak for some time.

The "half-stuff" now is fed into beating engines, then strained and run out upon the paper-making machine. All these best qualities of paper are "tub-sized"; that is, put through a bath of gelatine size and afterwards dried. The sheets are placed between zinc plates and rolled or glazed between heavy rollers before being sent to the finishing department, where they are sorted and counted into reams. Note-paper is usually packed in quires of 24 sheets. In every ream there are 20 quires.

The amount of paper used in the world is enormous. One mill alone, and that not the largest in this country, produces about 3,000 tons a week, and to make this it uses 4,000 tons of coal and uses 200 million gallons of water.

Thousands of Miles of Paper

We think of paper for printing and writing purposes, for making bags for the tradesmen, and brown paper for household use. If you were asked to make a note of other uses, you might

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CUTTING UP A REEL OF PAPER

For newspapers the paper required is usually made in great reels measuring a particular width Other paper-users require different sizes, and in the picture above we see the first huge reel as it came from the paper-makers' machines, being fed through another machine, fitted with knives adjusted to the particular widths required.

perhaps put down wall-paper, paper for wrapping cigarettes and blotting-paper.

But these are only a few of the vast variety of papers. There is paper for currency and Bank Notes, very specially made for the Bank of England, and every inch has to be measured up and accounted for. There are drawing papers, carpet felt, cartridge paper, butter paper, tracing paper, chart paper. Nor must we forget millboard, paste-board and cardboard, in all kinds of thicknesses and varieties.

For cardboard, brown paper, wrappings, and to fortify pulp for newsprint, the waste paper collected from homes and offices has become highly important in recent years. Over 15,000 tons of waste paper can be dealt with weekly by British mills.

During war-time strong sandbags were made of paper, as well as twines, cords, ropes, and petrol jettison tanks for aeroplanes. Paper is now fashioned into stair carpets, trunks and bags, milk bottles, towels, handkerchiefs, and even wearing apparel.

By Smokeless Engine

In a paper-works fire would be a particularly terrible happening, and the air has to be kept as free from smoke, soot and sparks as possible. In one large paper mill the bales of wood-pulp are hauled on narrow-gauge rails from the ocean-going ship to the stackyard, and from this yard to the "beater" or mixing-room by a small though immensely powerful locomotive that has neither fire nor smoke and yet is a steam engine.

Instead of having a furnace the engine is taken every four hours to a boiler-house to be charged with super-heated steam.

Messrs. Stonhill and Gillis Ltd. and Messrs R. T Tanner & Co Ltd.

ESPARTO GRASS FOR HIGH QUALITY PAPER

For centuries nearly all our paper was made from cotton and linen rags, but in 1850 experiments were made with Esparto grass which grows in the swampy areas of North Africa Esparto is still used in large quantities for the manufacture of good quality paper. In this picture a cargo of Esparto grass, brought from Sfax in North Africa, is being unloaded into barges in London's Docks.

COTTON GROWING AND SPINNING

H. J. Shepstone.

COTTON-PICKING IN CALIFORNIA

The cotton harvest in full swing at Fresno, in the San Joaquin Valley. The pickers are pulling off fully ripened bolls, seeds and all. Harvesting cotton is not a matter of a day or two, as with grain crops, for the bolls ripen at different times, and the first may be picked months before the last.

THERE is nothing particularly noticeable about an ordinary cotton bed sheet, considered merely as a sheet. It is just two sets of threads, crossing one another at right angles. If you look at any one thread closely, you will see that it passes alternately over and under the threads in its path.

But, like many other common things, it becomes quite interesting when its story is explored. Who first discovered how to twist the fibres gathered from the ripened bolls of the cotton-flower into a thread of cotton no one knows. It happened long centuries ago and most probably in India. Long before anyone in England knew what "cotton-wool" was like or how to spin it into cotton and weave it into cloth, the making of garments from cotton material had become quite an industry in India and other parts of the East.

Calico and Muslin

Cotton cloth was being made at Calicut on the West coast of India when Europeans landed there at the end of the fifteenth century. It was from this town that the name "calico" came, just as another kind of cotton material, muslin, first took its name from Mosul in that country not very far from India known to-day as Iraq.

Since those days the cotton industry has become a great and important industry in many countries and nowhere more so than in Britain. Lancashire is said to owe much of its success as the great centre of the cotton-spinning industry to its humid atmosphere which prevents the fine threads in the early stages from breaking too easily. In drier climates where cotton-spinning was at first a failure this humidity has to be produced in the factories by artificial means. The cotton plant itself grows best in sub-tropical climates.

Look at a piece of cotton cloth—a sheet or a handkerchief. If a single thread be pulled out and untwisted, it is found to be composed of a number of very fine fibres. Under a microscope each fibre resembles a tiny flattened tube with a corkscrew-like twist in it. This twist is found only in cotton fibres

and is a great help in spinning, as it makes them interlock and cling to one another.

The cotton used for our sheet came most probably from the southern part of the United States, which produces more than half the world's supply of raw cotton. The cotton-growing district there covers about 500,000 square miles, or, say, ten times the area of England. In one year it may yield as many as 16,000,000 bales, each weighing 500 pounds; that is, over 3,500,000 tons of the material.

In case you should wonder where the rest of the world's cotton is grown, we will add that India comes next to America as regards quantity produced, while Egypt supplies cotton of the highest quality. To make the list of cotton-growing countries fairly complete, we must include in it the West Indies, Mexico, Brazil, Peru, Nigeria, British East Africa, Russia, Iran, the East Indies, Asia Minor, China and Japan. Australia has also become a cotton-growing country and in Queensland, which has long been well-known for its wool-producing sheep, the farmers are now cultivating the cotton-plant as well. Nearly all the cotton that Australia needs is now produced on her own lands.

How the Cotton Grew

Last April, on a certain cotton estate, machines were busy drilling seeds in rows about 4 feet apart. From these seeds sprang little plants, which were thinned out with hoes till only one remained every foot or so. Now and then the farmer cleaned the ground between the rows with a machine called a cultivator, to keep down the weeds which grow so quickly in these parts.

Two months after sowing the plants were bushes 18 inches high, with leaves rather like those of ivy. On them flowers presently began to open—creamy-coloured, suggesting hollyhock blooms, but with longer bells. The shrubs went on growing till they were 3 feet to 4 feet high, and the earliest flowers dropped their petals. At the centre of each flower was a seed capsule or fruit, called a boll. By August many of the bolls had split open, and out of them burst masses of white down, clinging to a large number of black seeds. The down was raw cotton.

Will F. Taylor.

THE MOST USEFUL OF FLOWERS

A "close-up" of cotton flowers just come into bloom. Seen from this point of view they resemble poppies, but actually they are more like hollyhock blossoms.

Coloured people—negro men, women and children—then began to pick the cotton, and the picking lasted till well on into the autumn. As fast as the cotton was gathered it was passed through a machine named a gin, which separated all the seeds from the fibres. The seeds weigh a good deal more than the lint, that is, the cotton itself.

At one time they proved themselves a great nuisance to farmers, who were at their wits' end to know how to get rid of the huge piles of seed that collected round the ginning-mills. But to-day the seed is a valuable part of the crop. Oil squeezed from it is used for cooking, soap-making, and many other purposes; the spent pulp makes a splendid cattle food; and even the husks have a use as fertiliser.

Commonwealth of Australia

WHAT COMES FROM THE FLOWER

The ripened seed-capsule or boll of the flower has here opened, and masses of the white down which we call cotton have burst out of it. This particular boll was grown in Queensland, Australia.

Enemies of Cotton

The ginned cotton is put up into bales, which are squeezed in a powerful press to reduce their size, and sewn up in sacking. It is then ready for sending out into the cotton markets of the world.

The cotton-farmer, like other farmers, is more or less at the mercy of the weather, which may be too dry or too wet, and may favour the spread of the pests that attack the cotton plant.

Some of these pests are kinds of fungus, others are insects or their caterpillars. The worst plagues of all are the cotton-worm, which gnaws away the leaves; the boll-worm, which devours the buds and young bolls; and the boll-weevil, which feeds on the lint, and is the greatest enemy of American cotton-growers. It invaded Texas in 1892, and since then has spread so much as to wipe out altogether the finest variety, Sea Island cotton, which fetched the best prices because its fibres were exceptionally long.

Some planters now use aeroplanes to scatter poisonous powder over their fields and destroy some, at least, of their tiny foes.

Cleaning the Cotton

Imagine now the bales of cotton to have travelled some thousands of miles by land and sea and to have reached one of the many spinning-mills in Lancashire, which for the last 150 years has been the greatest cotton-spinning and weaving centre.

The cotton in the bales contains a good deal of dust and dirt, fragments of seed, shells and leaves. The fibres run in all directions, and many of them are knotted together. Before the cotton can be spun, it must be both cleaned and "straightened out."

So it is flung into a bale-breaker, which mixes different grades of cotton

together, and tears any lumps apart. Then it undergoes a good beating in another machine, and has most of the dirt and rubbish knocked out of it. A third machine finishes the beating and converts it into a thick and delightfully soft sheet of "cotton-wool," such as one buys for packing purposes. If you examined a piece of cotton-wool under a microscope, you would see that the fibres still lie "anyhow," in a regular jumble.

Straightening the Fibres

So the sheet of cotton-wool is fed into a carding machine, between a great revolving cylinder and an endless belt travelling close to the top of the cylinder, and in the same direction, but at a different speed. Both of these parts bristle with millions of short wires. The difference of speed makes the wires act like combs and drag on the fibres, pulling them so that they all tend to lie in the direction in which they are moving. The cotton leaves the machine in the form of a web or veil about as thick as stout paper. This web is drawn through a funnel, which compresses it into a "sliver," as the workpeople call it, 1 inch wide and ½ inch thick.

But the straightening is still far from complete. In another section of the mill you will see the slivers being "drawn." If a person holding one end of a piece of elastic walks faster than a second person holding the other end, the elastic will be extended and become thinner. The same principle is used in drawing cotton slivers.

Six slivers are passed together through three parallel sets of rollers, placed one behind the other and turning at different speeds, the front set six times as fast as the back set. The single sliver into which they are mingled is of the same size as each of the original slivers, and this means that every one of the partners has been lengthened six times. The process is repeated twice more and the drawing-out does not cease till a sliver is a mixture of 216 original slivers. All this dragging at the fibres has straightened them out wonderfully.

Spinning Cotton into Threads

Before the cotton can be spun, the slivers have to pass through four other machines, which convert them into coarse, loose threads, slightly twisted, called "rovings."

The drawing out of the rovings, and the twisting of them into threads fit for weaving, are done by either a ring frame or a mule, both of them very wonderful devices.

Let us glance at the first of these: On it are hundreds of upright steel spindles, each carrying a bobbin and revolving thousands of times a minute inside a hole in a horizontal rail which moves slowly up and down. Encircling each spindle, and fixed to the rail, is a steel ring, with a grooved lip. A small curved piece of wire, known as a "traveller," is clipped loosely over the lip and is able to slide freely along it. The roving being spun passes through the "traveller" to the bobbin.

As the bobbin revolves it pulls on the roving, and the roving makes the traveller fly round and round the edge of the ring. If the traveller could keep up with the bobbin, the roving would merely be twisted, but there is friction between traveller and ring, and the ring is therefore always losing ground. The result of this is that the thread, besides being twisted, is wound steadily on to the bobbin. The up-and-down movements of the ring ensure that the winding is done evenly from one end of the bobbin to the other.

Now a few words about the other kind of spinning machine, the self-acting "mule." It is a very large apparatus, being about 200 feet long and 12 feet wide and consists of a fixed frame on which are up to 1,200 bobbins of rovings and a moving carriage with as many spindles on it. The carriage keeps travelling a few feet away from the frame and then back again on wheels

Australian News and Information Bureau

COTTON GINNING: SEPARATING THE SEED FROM THE FIBRE

In this photograph we have on the left the seed cotton as it comes from the flower. After being dealt with at the ginneries the seed seen in the centre is extracted and the raw cotton lint or fibre on the right is ready for the next stage in the various processes of cotton manufacture. This sample was grown in Queensland, Australia.

running on rails. During an outward journey the spindles draw out and spin the rovings, and during an inward journey they wind the spun threads on to the bobbins. A single mule spins and collects several miles of yarn every minute.

Weaving the Yarns

A woven fabric is made up, as we have noticed already, of two sets of threads, the ***warp*** threads and the ***weft*** threads. The warp threads run from end to end of a piece, and the weft threads cross and are interlaced with them.

The threads intended for the warp of a length of cotton cloth are wound side by side on to a weavers' beam, which is placed at, say, the south end of a machine called a loom. If we take any thread and follow it northwards through the loom, we see that it passes first between two horizontal rods (lease bars) then through an eye at the centre of a vertical wire (a heald), next between two of many upright wires in a swinging frame, named a reed, and on to a winding-on roller at the north end of the loom.

For weaving a simple fabric, such as a sheet, all the "odd" healds are attached to the same rods top and bottom and move together, and all the "even" healds to another pair of rods.

The bottom bar of the reed, named the sley, is wide enough on the north side to form a ledge, on which a shuttle slides to and fro from a shuttle-box at one end of it to a shuttle-box at the other. The shuttle is pointed at both ends and contains a "cop" or reel of weft thread.

Now let us watch the actual opera-

tions of weaving: The mechanism of the loom first "opens the shed" by pulling the "odd" healds up and drawing the "even" healds down. The warp threads, seen sideways, now enclose a lozenge-shaped space, and the even threads are all pressing against the sley. An arm, called a picking-stick, gives the shuttle a jerk. It flies over the "even" threads, paying out thread behind it.

Immediately afterwards, the reed moves northwards, its wires pressing the weft thread just laid by the shuttle into the north angle of the lozenge While the reed is swinging back the "odd" healds are lowered and the "even" healds raised, and the two sets of threads cross round the last weft thread, holding it firmly in place Things are then ready for the next throw of the shuttle.

This series of operations is repeated as long as the weaving continues

Will F. Taylor.

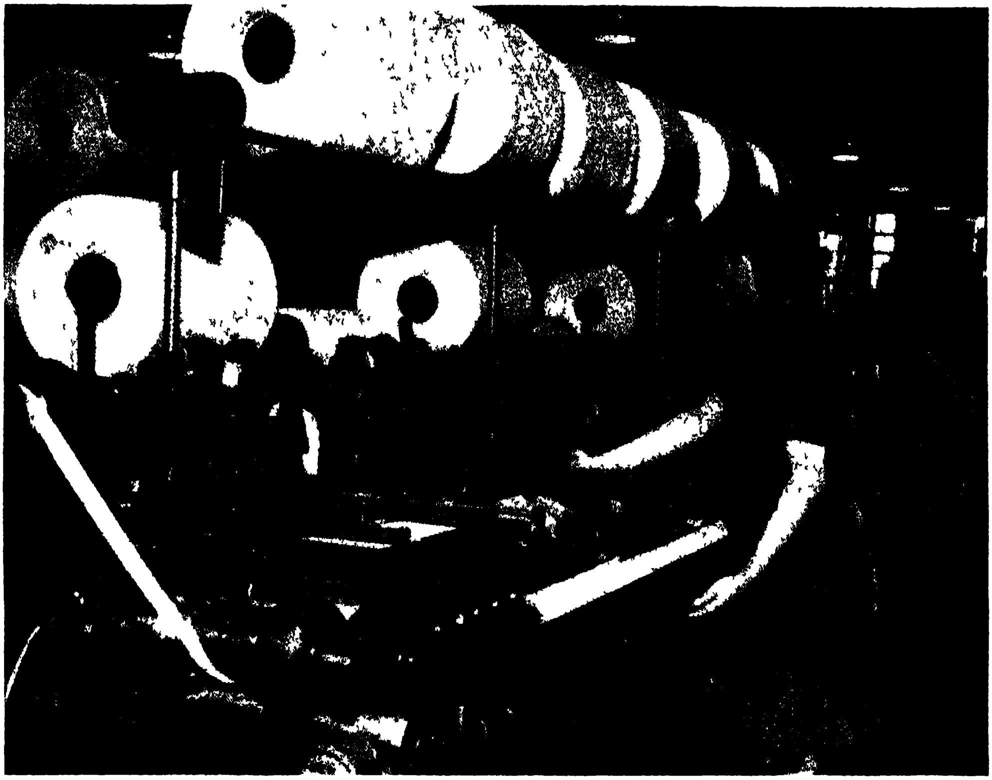
IN THE DRAWING SHED

The machines in this picture are each taking in six slivers, or ribbons, of cotton wool and combining them into a single sliver, which is the same size as an original sliver, and therefore six times as long The pulling-out action straightens the fibres

In a Weaving Shed

The weaving shed of a mill is a very noisy place. It may contain as many as 2,000 looms, all going clickety-click, as their shuttles fly backwards and forwards 200 times a minute—too fast for the eye to watch them.

The looms are probably of several different sizes, the largest of them able to weave cloth up to 12 feet wide. Some of them have very wonderful mechanisms. Here is one which automatically supplies the shuttle with a fresh cop of weft yarn when required, and stops instantaneously should a warp thread break. Over there is a loom using weft threads of several different colours, and changing the shuttles automatically whenever a change of colour is needed.



Topical Press.

MODERN MACHINERY IN LANCASHIRE'S MILLS

The manufacture of cotton goods began in Lancashire soon after 1700. Since then the industry has undergone many changes: machinery first came into use about 1780, with the inventions of Hargreaves, Arkwright and Crompton. The improvement of cotton spinning machinery is still going on, and this photograph shows a new model Nasmith comber in operation in a big Lancashire mill

By it stands a loom fitted with the wonderful Jacquard apparatus, which enables the most elaborate patterns, and even pictures or facsimiles of writing to be woven in one colour or different colours. It is controlled by a series of cards, with holes punched in them, which cause certain warp threads to be raised before each trip of the shuttle.

Like a Piano Player

One may well compare it with a piano "played" by a punched roll of paper, the difference being that in the loom a hole relates to one or more warp threads, whereas in the other case the holes control notes in the piano

To return to our sheet, or, rather, to the cotton cloth out of which it will be made: After leaving the loom it has the rough nap burned off it by gas burners. It then goes to the bleaching works, where it is washed, treated with chemicals, bleached, starched, dried, damped again, beaten, folded and pressed. It is then ready for the market, and for making into sheets.

King Cotton

The cotton-spinning and cotton-weaving industries are of enormous importance to Great Britain. There are in the world about 165,000,000 spindles for spinning cotton, and about 3,000,000 power looms for weaving cotton fabrics. Great Britain contains

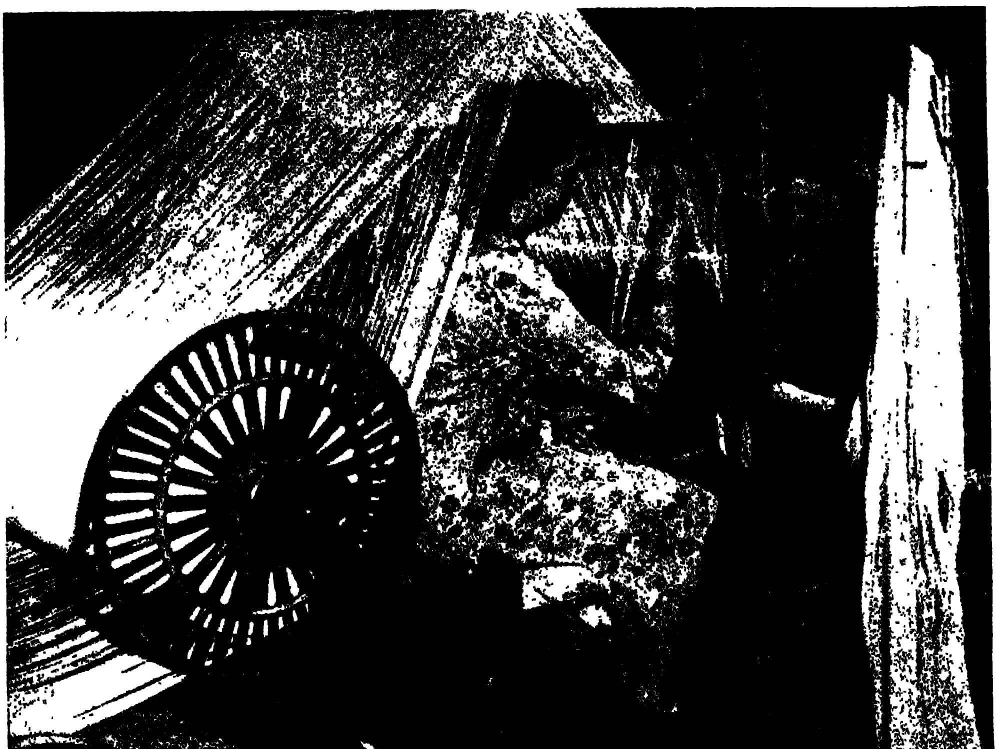
nearly 60,000,000 of the first and 800,000 of the second, and so is by far the greatest cotton-manufacturing country.

The products of her spindles and looms easily take first place, as regards value, in the list of her exports. In post-war years it has become even more important to keep up our exports of cotton goods to those countries, such as America, from which we obtain large quantities of the food we cannot grow ourselves as well as the raw materials on which our industries depend.

Lancashire was for long years the greatest cotton-spinning area in the world. It may be that her claim will be challenged sooner or later by other countries where the manufacture of cotton goods has made rapid strides in recent years. Even to-day, however it is safe to say that from China to Peru the people in many lands are wearing cotton garments made from raw material which was spun and woven in Lancashire.

Nor is Lancashire relying upon her reputation of the past to maintain her position against increasing world competition. New machinery has been devised and many mills have been thoroughly modernised. A Cotton Manufacturing Commission, set up by the Government, has studied every aspect of the organisation of the industry.

Experimental trials were made of new systems and the Cotton Spinners' and Manufacturers' Association pre-



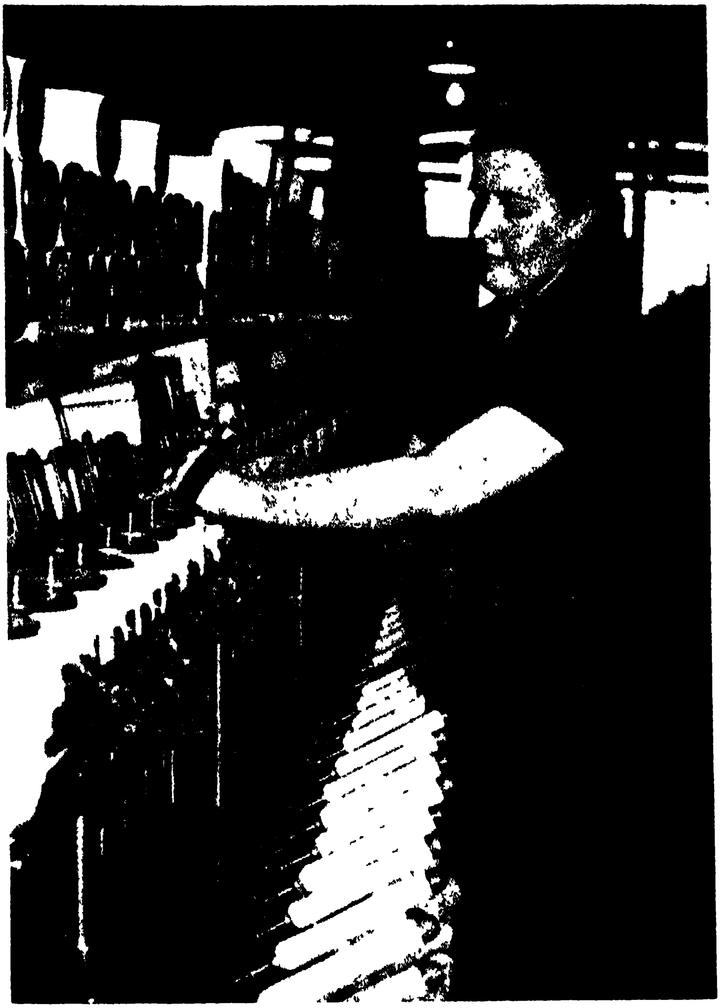
Topical Press.

WARP DRAWING IN A COTTON MILL

From the raw cotton the mills produce sheets, shirtings, towels, pillow-cases and the cloth for many articles of wear as well as for industrial purposes. Women, with their deft fingers, have always played a great part in the Lancashire cotton industry, and in this photograph is shown the process of warp-drawing : the reacher is selecting a thread for her fellow-worker, the drawer, to draw through the eye of the heald.

pared manuals of instruction in the new methods. At a stage in our history when the standard of living for the whole nation depends upon our exports to other countries, the great textile industry, which has contributed so much in the past to our prosperity, is determined to maintain its lead.

Some idea of the quantities of cotton piece goods which Lancashire mills produce can be judged from the fact that in one month alone in 1949, just on 90 million square yards of these goods were exported. In comparatively recent times other countries have developed the manufacture of cotton goods, but those made in Lancashire still hold first place so far as quality is concerned, and it is to maintain this supremacy that the leaders of the industry are striving to-day.



Topical Press.

WINDING FROM RING TUBE TO BOBBIN

The cotton yarn from approximately eight spinning tubes is joined together and run on to a flanged bobbin in one continuous length as part of the process of preparing the warp—the threads that run lengthwise in the cloth. A girl worker is seen using an automatic hand-knotter to tie the yarn from a ring tube to the bobbin.

Apart from the manufacture of cotton goods there are a number of by-products which come from the wonderful cotton flowers. We have seen how the seeds, which were once a nuisance, are now taken out in the first process of " ginning " and become the raw material for manufacturers of cattle cake, cooking oils and other purposes. Cotton which has not been spun into thread or yarn is specially dealt with to rid it of greasy substances and make it absorbent. This is the cotton-wool which is used in hospitals and in the home. This same harmless cotton-wool when treated with certain acids becomes gun-cotton, a dangerous and powerful explosive.

The clean clippings from factories where cotton garments are manufactured are not by any means wasted. High-grade papers are made from this "waste," and our banknotes are printed on this type of paper, which differs

considerably in quality from the wood-pulp paper used for newspapers and most of our books.

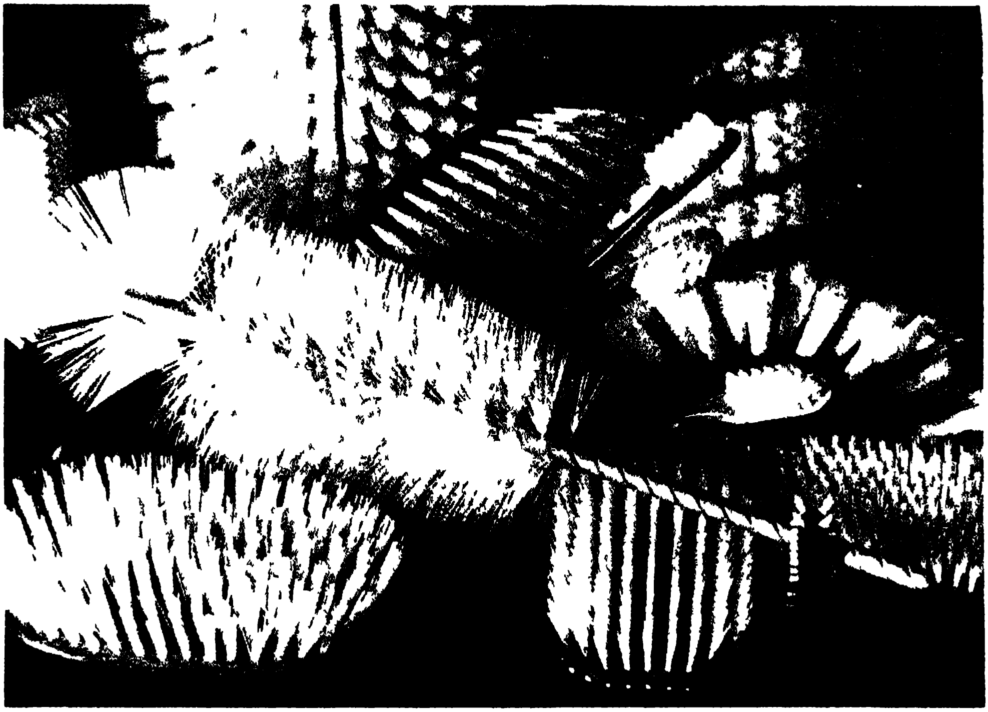
In this age when the scientist is discovering new methods of manufacture and new uses for old materials, a great deal of research work is being carried on in the cotton industry. The story of the fluffy cotton-boll with seeds clinging to its twisted fibres has not yet come to its end. Other chapters will one day be written about the new discoveries and developments in the uses to which the flower of the wonderful cotton plant can be put.

Imperial Chemical Industries, L'd

FINISHING TOUCHES

After being woven, cotton cloth has to undergo about twenty processes—which include singeing, washing, boiling, bleaching, pounding and rolling—before it is ready for market, that is, unless it is sold in the unbleached condition. This picture was taken in the finishing department of a mill, and shows cloth passing through rollers under heavy pressure.

FROM SILK TO RAYON AND NYLON



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ALL MADE FROM NYLON

Nylon is one of the most recent and one of the most amazing discoveries to be made in the textile world Its fine strong thread is not only used for garments and silk stockings, but, as this picture of various kinds of brushes shows, it can be used in many other ways The full list of the articles which can be manufactured from Nylon fibres is almost endless

AN old legend of the China of four thousand five hundred years ago tells how the wife of the Yellow Emperor Huang-ti, the lovely lady of Si-ling, began the Chinese silk industry. The empress is said to have encouraged her people to grow mulberry trees to provide food for the worms which spun the wonderful silken thread. The legend says that she herself reared silkworms and even invented a loom for weaving the thread into fabric. After her death, the empress was revered as Yuen-fi, the goddess of silk, and was worshipped down the centuries by the Imperial Court in the Forbidden City of Peking.

Whatever the origin of the silk industry—and none can say who it was that first discovered the real value of the grubs of the mulberry-feeding moth—we know to-day that the rearing of silkworms, sericulture as it is called, and the developments to which it has led, have given us clothes and fabrics of unsurpassed quality. Now, thanks to miracle discoveries by scientists and chemists, beautiful textiles are no longer luxuries which only the rich can afford, but are within reach of everyone. To-day nearly every one of us has something in his or her wardrobe or house which is the equal of such silk as was once an expensive commodity available only to the privileged few.

How the Silkworm Lives

In its naturally produced state, silk comes from the silkworms hatched

from the eggs of the mulberry-feeding moth, the *Bombyx mori* as scientists would call it. This moth, white in colour and with brown-striped wings, lays from between four and seven hundred eggs each so small and so light that nearly half a million would be needed to make a pound in weight. When the silkworm is hatched, it begins eating almost at once and continues eating for about eight or ten days. Then it sleeps for two days, wakes up, and—starts eating again. After thirty-two days of this life, the worm has developed from a tiny hairlike thing into a large amber-coloured caterpillar. It now coils itself up, horse-shoe fashion, and begins to spin its cocoon, sending the silk from two openings above its mouth and joining the two threads together and spinning them about itself. One caterpillar spins nearly two miles of silk, but much of this cannot be recovered. The silk thread is so fine that as many as 1,100 cocoons may be needed to make a pound of raw silk.

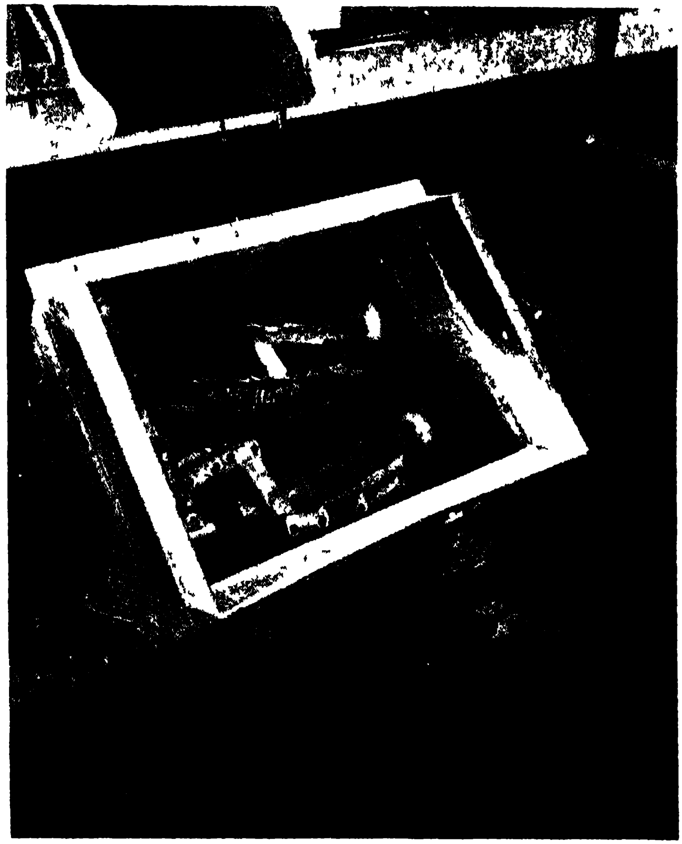
If the industry depended upon the silkworm, delicate and lustrous silk fabrics would probably still be beyond the pockets of most of us. But to-day, in *Rayon*, we have a man-made textile fibre that has all the shimmering richness of silk produced by the *bombyx mori* caterpillar and which constitutes a world-wide industry employing hundreds of thousands of workers.

WHERE RAYON BEGINS *Courtaulds Ltd.*

The story of Rayon, the fine man-made textile that has all the richness of natural silk, begins in the spruce forests of Canada and Scandinavia. This picture shows typical Northern Canadian Spruce ready for felling. At the pulp mills, cellulose will be produced by the many processes to which the logs are submitted. The large cellulose sheets will then be baled up and sent to the rayon factory.

Even as long ago as the seventeenth century an English scientist, Dr. Robert Hooke, was wondering whether there might not be some other way of manufacturing silk, whether it might not be possible "to make an artificial glutinous composition, much resembling, if not fully as good, nay better than ... whatever substance it may be out of which the Silk-worm wire-draws his clew"; but it was not until 1855 that the first artificial process was patented by a Swiss named Audemars, and not

until the early eighties of the last century when the hopes of Dr. Hooke were to be realised. Sir Joseph Swan, a famous English chemist and electrician, produced a silken thread in the course of his experiments in 1884 with materials for making electric-light filaments: a remarkable achievement which, however, he did not attempt to use commercially.



Courtaulds Ltd

THE BLADES OF A PULVERISING MACHINE

Alkali Cellulose is in sheet form. After it has been squeezed in hydraulic presses, it is torn and ground by the blades of a pulverising machine called a Pfleiderer These reduce the Alkali Cellulose sheets into creamy-white alkali cellulose "crumbs" which are then stored in large bins for a time to allow the caustic soda to complete its work.

First Artificial Silk

In the following year, Count Hilaire de Chardonnet produced artificial silk yarns and later had them woven into finished garments which he exhibited in Paris. At first, he copied the silk-worm, using mulberry leaves as his raw material, but later he found other substances which could be obtained more easily and cheaply. Count Chardonnet was the first to exploit artificial silk commercially, and his factories rose in France, Belgium, Switzerland, and our own country.

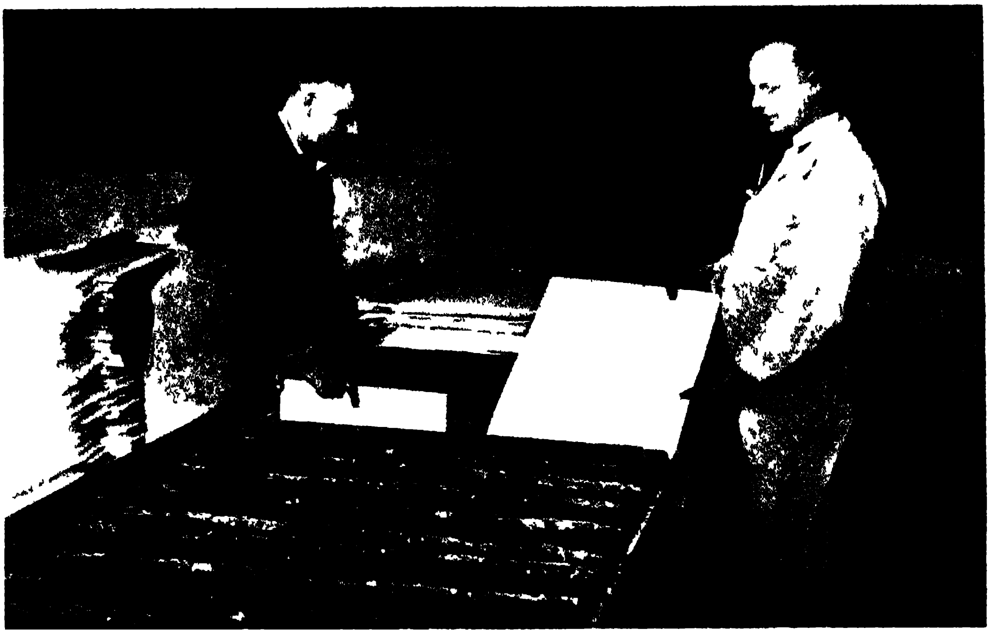
Meanwhile, another process was discovered and put to use in Germany, and in 1892 three British chemists, Cross, Bevan and Beadle found a way of obtaining a smooth thread from a cellulose solution which they called *viscose*. Literally, cellulose means *containing cells*, and it is the name given to the carbohydrate main element of the cell membrane of plants and wood.

Cross and Bevan now sought the help of one of Sir Joseph Swan's former colleagues, C. H. Stearn, whose associate, C. F. Topham, devised the method of rayon-spinning that is most widely used to-day. This viscose process yielded its first yarn in 1898 and at the beginning of the present century, British rights over this process were bought by the old-established and famous firm of Courtaulds which to-day is known the world over for the quality, variety, and richness of the rayon which it produces.

How Rayon is Made

There are various processes for making rayon: the *Cellulose-Acetate Pro-*

RAYON IN THE MAKING



When the cellulose reaches the rayon factory it is inspected and carefully stored until it is needed hen it is batched and weighed, and steeped in a bath of caustic soda This picture shows the sheets of cellulose being put into the bath before the liquid caustic soda is run in The caustic soda removes impurities and combines with the cellulose to form Alkali Cellulose

Photos Courtaulds Ltd

In these churns, carbon bisulphide converts the alkali cellulose crumbs into an orange-red mass called Cellulose Xanthate Cellulose Xanthate will dissolve in water to produce a honey-like substance called Viscose which gives its name to the Viscose process of manufacturing rayon illustrated in these pictures

cess, in which cellulose from cotton linters or spruce wood is used with acetic acid and acetic anhydride to produce a thick liquid which yields cellulose-acetate flake which, dissolved in acetone, forms the spinning " dope " from which the rayon filaments come; the *Cuprammonium Process*, in which pure cellulose is mixed in a solution of copper sulphate and ammonia to produce a sticky viscose solution from which rayon filaments come; and the *Viscose Process* invented by Cross, Bevan and Beadle.

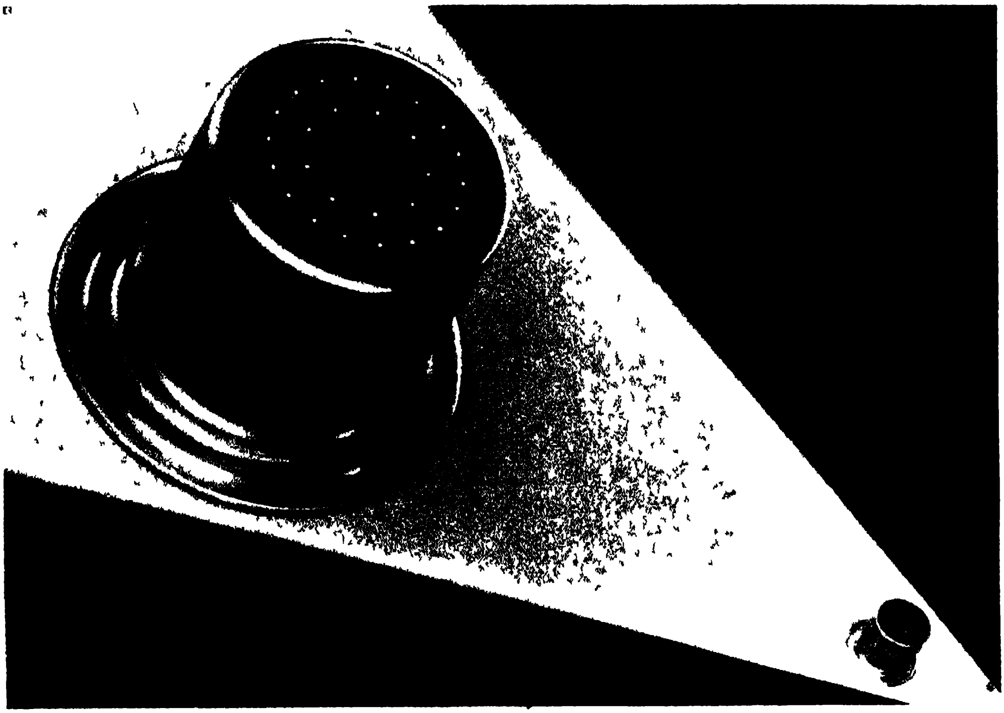
The story of Viscose Rayon begins in the spruce forests of Canada and Scandinavia where large pulp mills process the felled trees, stripping them, cutting them, crushing, cleansing, washing, scouring, and bleaching them; drying the product over cylinders heated by steam, and baling up the resulting cellulose—which looks very like large sheets of thick blotting-paper at this stage—for its journey to the rayon factory.

The cellulose requires careful handling; its weight and temperature are checked when it reaches the factory, and until it is required it is kept in a specially controlled atmosphere and submitted to frequent tests and checks. When manufacture begins, the cellulose is batched and weighed: then steeped in a bath of caustic soda. Caustic soda is used in vast quantities by the rayon industry and the part it plays in the manufacturing process is a highly important one. Not only does it remove any impurities—elements which are not required in the process—it combines with what is left to form Alkali Cellulose. This comes from the " bath " (which is really a long deep metal trough) in sheet form. Hydraulic presses squeeze part of the soda from the pulp sheets which are then torn and ground by the spiral blades and tooth-edged bars of pulverising machines. At this stage, temperature is still very important and is carefully controlled. The caustic soda has still not completed its work and the creamy-white alkali cellulose " crumbs " which come from the pulverising machines

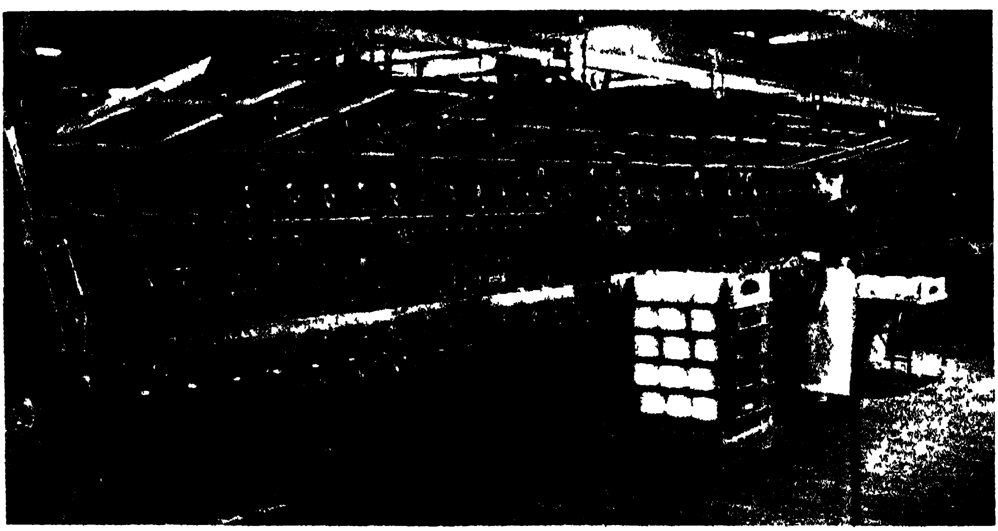
Courtaulds Ltd

VISCOSE

The honey-like substance flowing from the glass palette is Viscose. Two British chemists Cross and Bevan discovered that Cellulose Xanthate, when dissolved in water would produce viscose and it is on this fact that nearly ninety per cent of world rayon production depends.



Forced through the holes of a spinneret, the viscose emerges as Viscose Continuous Filament Rayon Yarn The number of filaments in the yarn is determined by the number of minute holes in the spinneret Spinnerets are usually made from platinum-gold alloy The actual size of a spinneret is about a third larger than that of the one shown on the right of the picture



Photos Courtaulds Ltd

C F Topham invented the way of rayon-spinning that is most commonly used to day As the viscose is forced through the spinneret, it is drawn into a spinning box which twists and winds the yarn into " cakes " ready for " doffing " (removing from the spinning boxes) The picture shows a spinning machine which has just been " doffed "

DOFFING *Courtaulds Ltd.*

This picture shows a "Doffer" removing a "cake" of rayon yarn from a Topham Spinning box. Notice the covering lid and ring of the box that he is holding in his right hand. After it has been "doffed," the yarn undergoes further cleansing processes on which depend its natural whiteness and thus the success of any dyeing processes to which it may be submitted.

are therefore stored in large bins for a time.

When the "crumbs" are ready, they are put into six-sided churns where carbon bisulphide converts their creamy-whiteness into an orange-red mass called Cellulose Xanthate. It was Cross and Bevan who discovered that this Cellulose Xanthate would dissolve in water, and it is on this fact that nearly ninety per cent of world rayon production depends. For when the Cellulose Xanthate has been dissolved in water in large mixers, the honey-like substance that is the result is the Viscose which gives its name to this particular process.

But the viscose is not yet in its purest form. Air or gas may have crept in, and there may be particles of undissolved matter and other impurities. The viscose is therefore stored for several days in "caves"—special cellars whose atmospheric conditions are carefully regulated. In the caves, the viscose passes through perforated layers of cloth between which are thick sheets of wadding. This is done several times, and simultaneously vacuum pipes draw off any gas or air.

This done, the viscose is forced through a spinneret. Spinnerets, made usually from platinum-gold alloy, are about the size of a thimble and are shaped like top-hats. Each spinneret may have up to 500 holes in its head, and it is from these that the thread emerges as Viscose Continuous Filament Rayon Yarn. The number of filaments in the yarn is fixed by the number of minute holes in the head of the spinneret; the yarn is called "continuous filament" because it is manufactured in a continuous thread. Metering pumps force the viscose through the spinneret, which is in an acid bath. As the threads emerge, they are drawn together and led out of the bath to pass round two wheels called *godets*. The surface speed of these godets also plays a part in determining the size of the yarn which is measured, in the industry, in *denier* (the weight of 9,000 metres of yarn in grammes). From the godets, the threads drop down a glass funnel, the lower end of which dips into a

circular metal cup with straight sides. This cup revolves several thousand times a minute, and the funnel is kept moving up and down by a lever.

This cup is more properly called a spinning box and is the invention of Topham. What happens is this: the thread already in the spinning box is pressed hard against the inside by centrifugal force and pulls on the thread coming down through the funnel. The thread is thus drawn into the cup as fast as it is formed, and, at the same time, given a twist. The up-and-down movements of the funnel cause layers of thread to be laid evenly one on top of the other, each layer a little nearer the centre of the box than the previous one. In this way, the spinning box twists and winds the yarn into "cakes" which are "doffed" (removed) from the boxes, wrapped, washed, bleached, dried and inspected before being packed ready for processing, dyeing, or dispatch to the spinning or weaving mills. These final stages of washing, purifying and bleaching are most important, for on them depends the natural whiteness of the rayon and so the success of subsequent dyeing processes which provide rayon in such a wide range of lovely tints and shades.

Spun Rayon

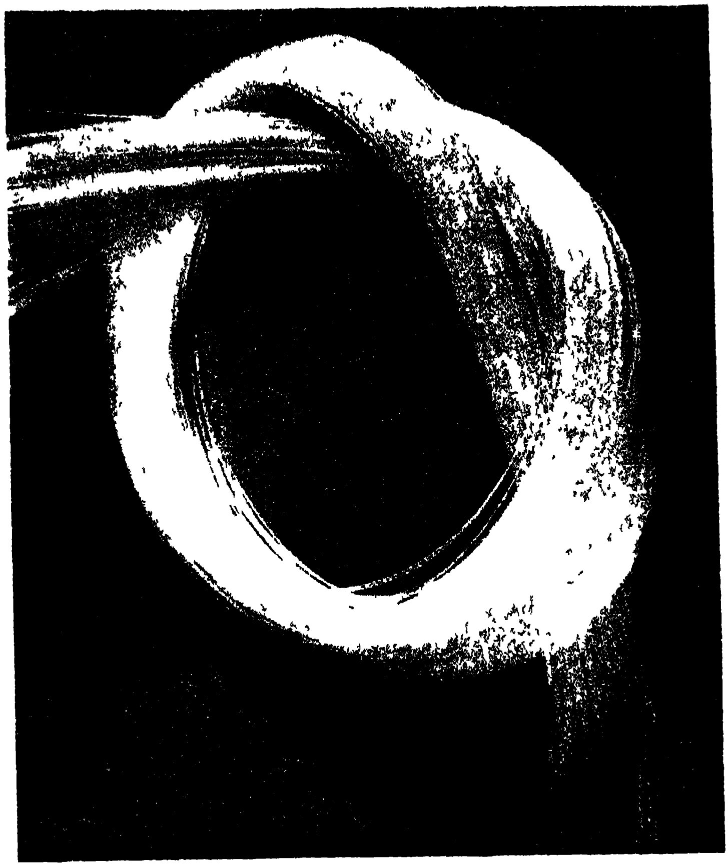
Not all rayon is required in continuous filament form. For making fabrics similar in texture to cotton, linen, and woollen cloths: for working in with cotton, linen, and wool: and for making new crease-resisting fabrics, *Spun Rayon* has been found to have many advantages.

Spun rayon yarns are made from viscose rayon staple. That is to say, from equal lengths or staples of cut rayon filament. Spun rayon is made in the same way as continuous filament rayon up to the spinneret stage. But as the thread emerges from the spinneret, it is gathered into an untwisted rope about the thickness of one's thumb

VISCOSE RAYON STAPLE *Courtaulds Ltd.*

Not all rayon is required in continuous filament form. For certain things Spun Rayon made from Viscose Rayon Staple is better. Viscose Rayon Staple is made up of rayon filament cut into equal lengths or staples. This picture shows a bale against which has been placed a card showing the size of the yarn and its quality.

which is cut into staples whose length is determined by the kind of textile spinning system subsequently to be used. Spun rayon, so important for its adaptability, is yet another of the developments which we owe to the firm of Courtaulds which has built the rayon industry in our own and other countries.



NYLON MONOFILS I.C.I.

Nylon fibres can be made in various sizes, ranging from gossamer, which is about four-thousandths of an inch, to extra stout, which is one fiftieth of an inch in diameter. This photograph shows the single filament known as "Monofil" but for textile purposes multi-filament is used, a number of filaments being twisted together.

The Rayon Industry

In 1947, the world production of rayon filament and rayon staple amounted to 1,990,710 thousands of lbs. The largest producer was the United States of America, with Great Britain second. But it was from Britain that America derived her rayon industry. The American Viscose Corporation was an offshoot of the British firm of Courtaulds and only passed into other hands as a result of the second world war when British assets abroad had to be sold to provide food and munitions.

Rayon in Britain is inseparable from the name Courtaulds. This famous firm was founded at Bocking, Essex, by the descendant of a refugee Huguenot family. To-day, the organisation is the largest of its kind in the British Commonwealth, with more than 20 factories and 25,000 employees in the British Isles alone. Coventry was the site of their first rayon factory and is still one of the chief Courtauld centres; a second great centre is Flintshire, North Wales. Overseas the firm has factories in Canada and in France. One of the most recent developments in which the firm has taken a major part is the establishment of British Nylon Spinners—a new organisation which has its headquarters at Pontypool, Monmouthshire.

Nylon, The New Textile

Nylon is the wonder fibre that made parachutes and glider cables during the war. We think of it first as a yarn for making the sheerest stockings, but it actually has nearly a hundred other uses—not only for dress fabrics, under-

wear, and umbrellas, but for tarpaulins, whaling ropes, canvases and in industry generally.

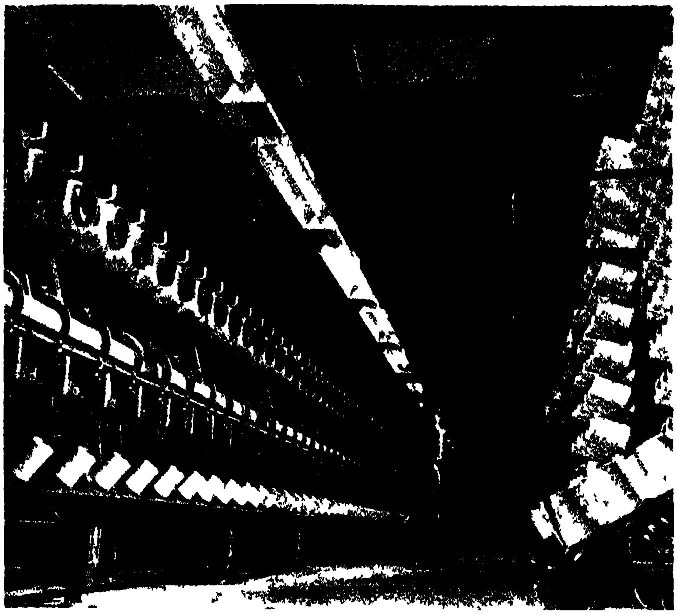
What exactly is nylon? Nylon is different from all other textile fibres. It is something quite new, made from the product of coal, air, and water. In Britain, for instance, the basic raw material in the manufacture of nylon yarn is benzene. We might be tempted to think that nylon is just another man-made copy of some natural fibre, that it is no more than just another "artificial silk." But nylon is neither of these; it is an entirely new textile fibre of surprising lightness, strength and beauty that we owe to the research work of a number of American chemists.

In 1928, these chemists, under the leadership of Dr. Carothers, were working in their laboratories at Wilmington, Delaware, on the structure of certain natural materials. They were studying the process called *polymerization*—that is to say the way in which chemical changes can unite a mass, whether large or small, into a substance that is permanently set. They began by studying *polyesters*—that is to say the products of condensation from the reaction between dibasic acids and glycols—and they discovered that they could spin fibres from the polyesters: and that when these fibres had cooled, they could be stretched to several times their original length and, while remaining very strong, had become lustrous and transparent. A new textile fibre had never been the main purpose of their research, but this was what Dr. Carothers and his associates had discovered.

MAKING THE NYLON HANKS *I.C.I.*

When the nylon filaments or monofils have been produced, they are cut into lengths and arranged in hanks ready for sending to the manufacturers. This picture shows a hank of Nylon monofil fibres, suitable for toothbrushes, etc., being tied before dispatch.

This was only the beginning. They wanted a stronger fibre and one with more elasticity, and they therefore sought to produce a *super-polymer* which would yield the desired fibre. (A *polymer* is one of a series of substances which are alike in composition, but which differ in molecular weight. A *super-polymer* is one which has a greater molecular weight than 5,000.) At last



Fox Photos

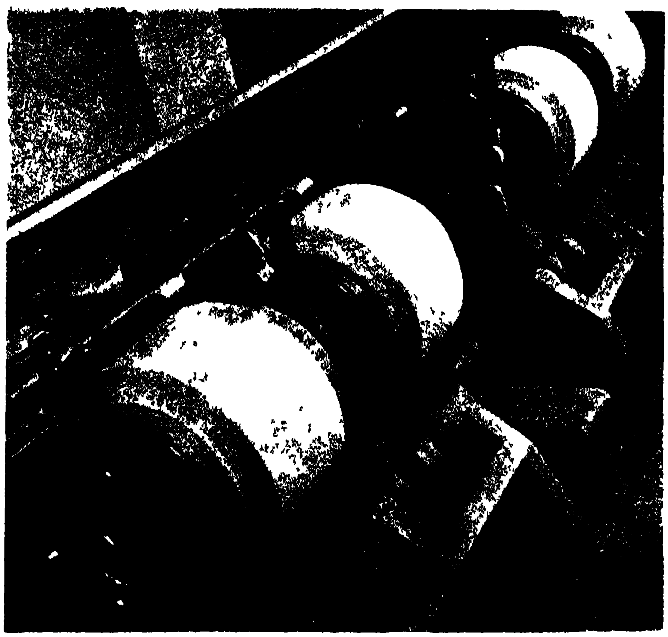
GUMMING NYLON HOSIERY YARN

The headquarters of the British nylon industry is at Pontypool, Monmouthshire and in this picture we see some of the machinery used in preparing nylon yarn for stockings.

telligibly, we can generalise by saying that nylon is a complex structure of carbon, nitrogen, oxygen and hydrogen which is built up into nylon polymer chips. Save that they are hard and not soft, these chips resemble soapflakes. They are melted, and the molten polymer is pumped through a spinneret. As the streams of liquid come from the tiny holes of the spinneret, they are cooled by air currents so that they form continuous filaments These filaments are then processed to produce nylon yarn.

When production of nylon began in Britain, they lighted on polymer "66," from which they produced nylon in their laboratories in 1935. Commercial production of the fibre and of garments made from the fibre did not begin until 1939, and we all remember the wonder and delight with which the ladies greeted the nylon stocking.

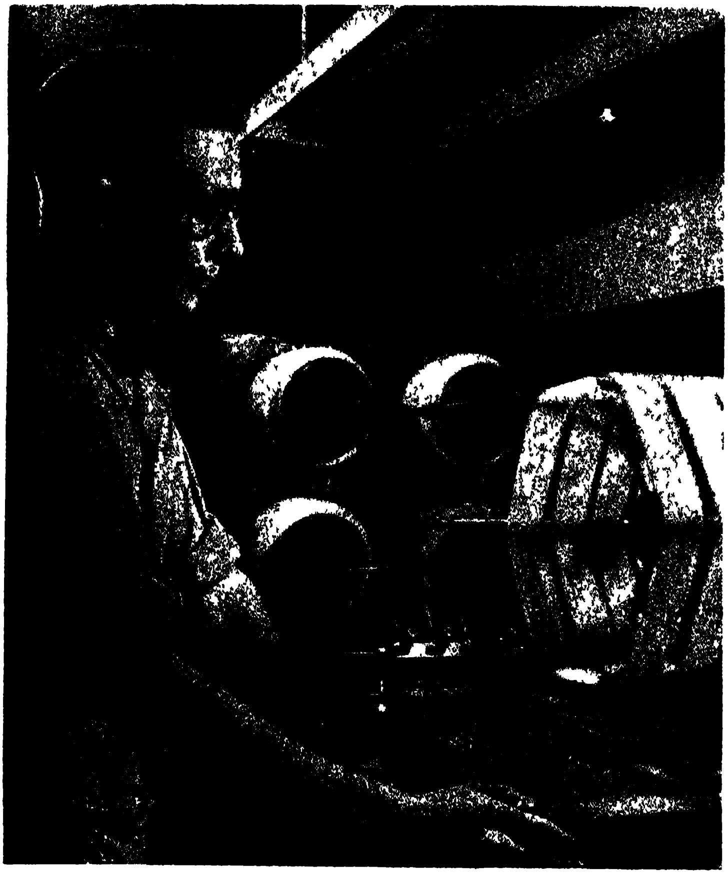
Chemists would tell us that polymer "66" is "obtained by heating the reaction product of adipic acid and hexamethylenediamin," that "each molecule of these reagents contains six carbon atoms." But speaking less scientifically and—for those of us who are not chemists, at any rate—more in-



Fox Photos.

THE LAST STAGE IN NYLON SPINNING

In this picture we see nylon yarn being wound on to spinning cylinders, which is the last stage in the spinning process. Nylon is used to-day for more than a hundred different products.



Fox Photos

TESTING NYLON

Like rayon, the size of nylon yarn is measured in the industry in *denier* (the weight of 9,000 metres of yarn in grammes). This picture shows us a worker in a British nylon factory testing yarn for denier It seems incredible that so light and fine a yarn should have so many uses and such powers of resistance to wear and strain.

every bobbin of yarn made was urgently needed for war purposes. But to-day, this yarn that is finer than silk is being used for dress materials, curtains and coverings, underwear, and ties and eiderdowns, as well as for tents, hammocks, blood filters, raincoats, and industrial purposes. Moreover, nylon can be combined with wool, silk, or rayon to make special high-quality fabrics.

Imperial Chemical Industries Ltd. and Courtaulds have together founded the firm of British Nylon Spinners Ltd. Their new factory at Pontypool, Monmouthshire, with a floor space of a million square feet, will employ 2,000 workers when the plant is in full production.

Since nylon is a new fibre, with new qualities, many questions have been asked as to how things made from nylon should be treated and how they will wear. We know that nylon is strong, that it is very fine, and that it is extremely light (an American firm has recently marketed a nylon nightdress weighing as little as five-sixteenths of an ounce). But it is also tough and resists rubbing. It is so smooth that when it is washed the surface dirt comes away very easily. It also dries very quickly after washing and, what is more, dries crisply and smoothly so that it does not have to be ironed. The housewife who washes her stockings, for example, will find that they dry in an hour or two—if they are made of nylon; and she will know that since they are made of nylon, she must never attempt to iron them.

Nylon fabrics can be ironed, however, and they have the advantage that they will not attract moths or other fabric-destroying insects. Nylon, too, is damp-resisting, and many yachts now have their sails made from the wonder fibre. It has indeed so many advantages that the uses of this amazing textile discovery are continually increasing.

THE ROMANCE OF WOOL

Topical Press

WHERE THE FAMOUS HARRIS TWEED IS MADE

From the Shetlands to the Hebrides the ancient craft of hand-weaving is carried on to-day much as it has been for centuries past Harris tweeds are noted throughout the world, and here we see a man and his wife in their own home on the Island of Harris working together on the production of the famous cloth. This industry is still carried on independently in the cottage and the mills send agents to collect the tweed from the weavers

OF all the animals in this world, the sheep is one of the least respected "Silly as a sheep" is quite as much an everyday expression as is "brave as a lion."

Yet, so full of contrariness are the natural laws which govern us, that while the lion gives to mankind little that is of value, the sheep is one of our greatest friends. Living, it helps to clothe us; when dead, it affords us nourishing and succulent food.

It is with sheep in the living state that we are going to deal here—with the sheep whose coats of fine wool are responsible for one of the most important textile industries in the world.

The industry of wool-making has been associated with the British Isles for untold generations We find references to it in the writings of Pliny, that great historian of an early civilisation and there is abundant evidence to prove that whilst wool was a commonplace article amongst the ancient Britons, the civilised Romans were utterly ignorant of its existence prior to invading our shores

British Cloth for Roman Soldiers

But it was the Romans who first marshalled together all the known facts concerning wool, and established a common centre of manufacture. They commanded that woollen goods should be made to clothe their mighty armies, and before many years had passed Britain was recognised throughout the early world as the main source of a new and remarkably useful industry.

The passing of years has not deprived our island of that fame. To-day, as yesterday, British woollen goods are reckoned the finest in the world The

reason for this is two-fold. In the first place, the pasture-lands of England support grasses that are eminently suitable to sheep, and therefore to the growth of wool; in the second, sheep are temperamental creatures, and years of experiment have shown that if a sheep is taken from one locality to another, the characteristics and quality of its wool will quickly change. The Lincoln sheep, for instance, is famous for the long and lustrous wool it naturally grows; but put it into Sussex and the length and lustre would quickly disappear.

Preparing the Sheep

Because of this relationship between sheep and pasture, and because there are many varieties of pasture-land in the British Isles, every possible type of wool can go into the factories for manufacture and ultimate export to every corner of the globe. There is Shetland wool, which is finest for knitting yarns; Welsh wool, magnificent for flannel manufacture because it attains its limit of shrinkage during its first wash; Cheviot wool, unsurpassed for the manufacture of famous Scots tweeds, and Scottish wool which, because of its rough, long fibres, is particularly suitable for carpet manufacture.

In addition considerable quantities of wool are imported from Australia, New Zealand and South Africa to be manufactured into various kinds of cloth and hosiery. Bradford in Yorkshire is the centre of the greatest wool-manufacturing district in the world. The West of England and South Scotland are also famed for the high quality of their woollen cloths.

You know, of course, that wool is the fleece or coat of sheep. Its preparation for removal from the living animal is the first task.

This preparation consists of washing. The sheep are brought in from pasture and herded together in an immense pen (or railed-in enclosure), next to which is a long, narrow tank of water. Then, one at a time, they are driven along an enclosed passage which leads from the pen to the tank, and as they pass along a strong spray of hot or warm water is shot over them. The purpose of this is to loosen the dirt in their thick and curly coats.

Next, still in single file, they pass into the tank of water and swim towards its distant end. The friction thus set up causes the loosened dirt to fall from their coats; finally, as each sheep scrambles from the tank, a strong douche of pure water thoroughly rinses it.

After washing, the sheep are put to pasture on land entirely free from straw and gritty matter, so that the wool remains clean while it dries in readiness for shearing.

Until a few years ago sheep-shearing was a long, slow task, each animal having to be clipped by hand. To-day hand-shearing is still practised, but the shears are driven by electricity, allowing each man to shear anything up to two hundred sheep every day. The record of 456 sheep in nine hours was made in New Zealand in 1953

Farewell to Winter's Coat

To watch a skilled sheep-shearer at work is a really fascinating experience. Holding his shears lightly in one hand, he stoops over the animal, slips the shears into its coat—and the thick and heavy fleece immediately begins to peel off, just like the skin of an orange. Since the highest prices are paid for fleeces in one piece, an important part of his job is to see that he does not break the long and even process.

As far as the living sheep is concerned there is, of course, not the slightest pain or discomfort. In fact, since shearing is done only in the warm weather, the sheep is no doubt only too pleased to be rid of its heavy winter coat!

SHEEP-SHEARING IN ENGLAND'S PASTURES

Central Press.

As far back as the Norman Conquest wool-growing was a main source of wealth in England and our earliest prosperity as a trading nation was due to our wool and cloth experts. In the picture above is seen the first stage in the great woollen industry when the fleece is taken from the sheep with the aid of a clipping machine which has now displaced the old-time shears.

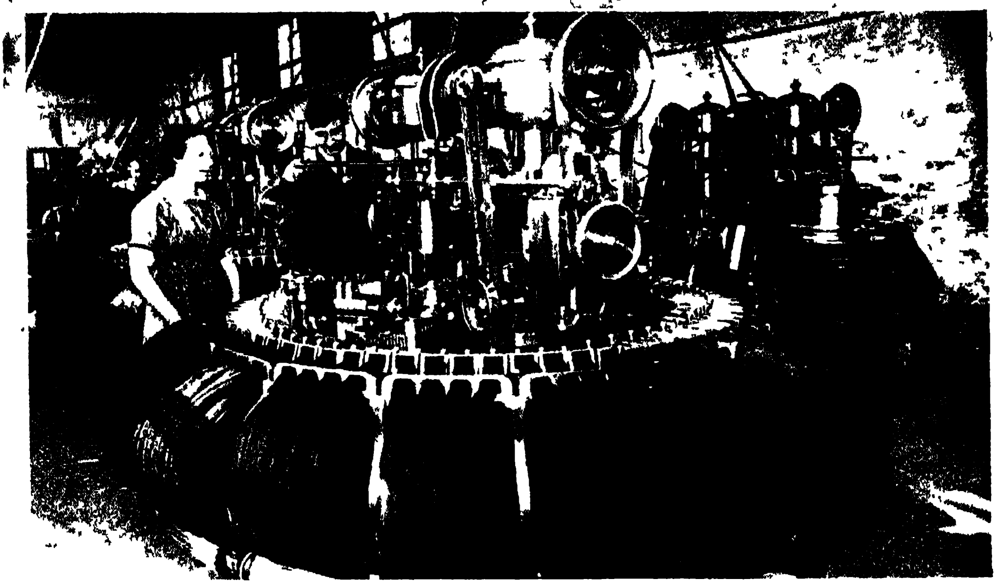
SORTING AND BLENDING WOOL

John Foster and Son Ltd

On reaching the spinning mills, bales of wool are opened and their contents carefully sorted by experts, who quickly separate the various grades After being washed and thoroughly dried, the wool is stacked in piles containing layers of the different qualities needed for a particular blend It is then passed through machines which tear the fibres apart and mix the layers

Sport and General

This machine, called a teaser is one of those used for blending the wool It contains a rapidly revolving cylinder, armed with tenterhooks The wool, after blending, has its fibres further pulled about by carding or combing machines and drawn out into slivers, in which form it is sold to the wool spinner



The yarn used for making " woollen " goods contains fibres of all lengths and lying at all angles to one another, whereas that for the weaving of worsted cloth has the short fibres removed from it by combing, and the long ones left carefully straightened to lie in the direction of the yarn

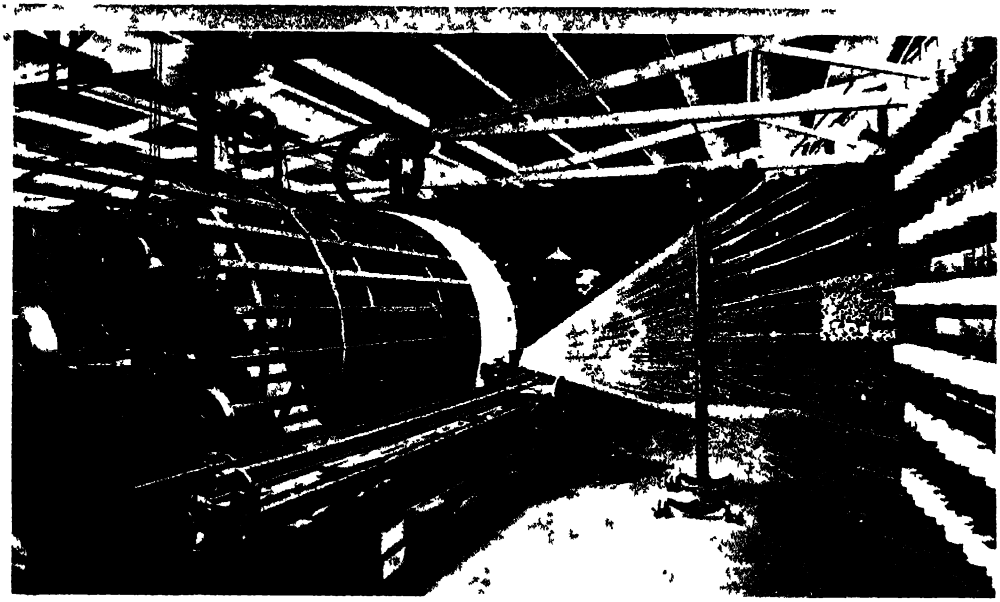
Photos Sport and General

The pictures on this page show two machines used in the preparation of slivers for yarns At the top is what is called a Noble comb, at the bottom a strong box for recombing the slivers Both of them, as you will gather from the illustrations, are very complicated.

READY FOR THE SPINNER

Sport and General.

The objects being carried by this girl are known as " box balls," a box ball being a bundle of slivers of combed and untwisted wool fibres. They will be drawn out and spun into worsted yarn. Box balls may be regarded as the finished product of the woolcomber, and the raw material on which the worsted-spinner works.



Commonwealth of Australia

The warping department of a woollen mill in New South Wales is here seen Hundreds of warp yarns are being wound on a great circular frame from which they will be transferred to the warp beams of looms The carriage through which they all pass moves along the runway in front of the frame

Sport and General

This picture was taken in the weaving shed of a Yorkshire woollen cloth mill We get a back view of the nearest loom The warp threads are travelling into the page, as it were through eyes in the healds which lift some of them and depress others, so that the shuttle may be thrown between them The cloth being woven is evidently of great width

Dorien Leigh Ltd

HAND-WEAVING IN THE SHETLANDS

Although wonderful machinery has been invented for cloth weaving it has not by any means eliminated the old craft of weaving by hand. In the Shetland Islands some of the finest hard wearing tweed in the world is produced and here we see an elderly woman at her spinning wheel

When the manufacturer receives the wool his first task is to clean or *scour* it; for despite the washing it received when on the back of the sheep, and the careful pasturing which followed, it has naturally picked up all sorts of stray foreign matter.

Scouring calls for great care; bad treatment can injure the texture of the wool, and also, unless the cleansing is both thorough and gentle, the various dyes to which it will possibly be subjected will not take properly

A scouring machine is a tank about 60 feet in length, its interior fitted with a series of rollers and nozzles. The end into which the wool is fed contains very hot water, which, like the hot spray originally given to the sheep, loosens the dirt The wool is steeped in this water, after which the rollers move and carry it forward into warm water, then on into water slightly colder, and so forth, again and again, through waters whose temperatures gradually decrease, until, at the far end of the tank, it meets with pure rinsing water. All this time the nozzles have been ejecting water on to the wool, maintaining the correct temperatures and forcing the dirt from it in preparation for its next process.

The grease in wool has a good commercial value and the water in which the wool is washed is afterwards treated with acid to separate the fats.

Now, one of the most dread diseases known to mankind lives in wool; some wools, indeed, are so prone to carry the germ that the British Government enforces their disinfection before they are passed into factories for the manufacturing processes which follow. Persian lamb is one of these wools; the germ it carries is known as *anthrax*, and was, until a few years ago, a terrible enemy of the wool merchant.

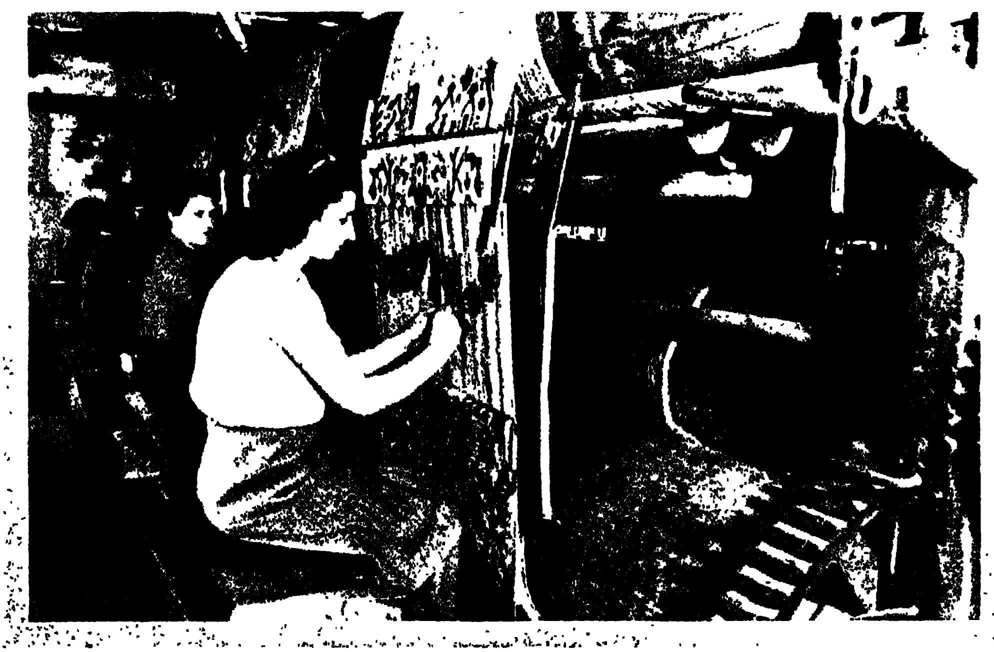
Cleanliness, therefore, is the first consideration of the experts who sort the wools into different grades; indeed, cleanliness in its highest possible form is maintained throughout

Crude brown wool grease is useful as a lubricant, but when refined the substance is known as lanolin which is more readily absorbed than most other fats when rubbed into the skin. It is also antiseptic to some extent. For these two important reasons it is largely used as a basis for face creams and ointments.

After washing comes the drying process—and although drying would seem to be a simple matter, in this case it is governed by a fast, stern rule: namely, that gentle and even drying *must* be enforced; for wool carelessly dried, either too much or too quickly, is considerably lessened in value.

There are many types of machine in use, but one of the most popular in this country is known as the *Jumbo*. It is a massive, churn-like construction into which the wool is emptied following its passage through the washing apparatus. Once it has received its precious cargo, the machine is set in motion; it rolls and rolls, the great masses of wool slide through it, and warm air, ejected into the Jumbo, gently but firmly rids the wool of its moisture. When it is finally withdrawn, the wool is soft, clean, and correctly dried.

From this stage onwards the various processes through which the wool passes depend upon the ultimate uses to which it will be put; knitting wools, for instance, receive vastly different treatments from wools destined for carpet manufacture. To follow all the processes, making only the briefest of examinations of the wonderful machines involved, would supply us with enough material for the writing of several books; here we have only



Mirror Features.

WEAVING THE PATTERN ON A WILTON CARPET

Although machinery plays an important part to-day in the making of the world-famed Wilton carpets, the skilled hand-worker still has an equally important place. Some of the carpets may be produced on a modern loom at the rate of a hundred a week, but in the photograph above we see hand-weaving from squared paper patterns in progress. With an intricate pattern a carpet on the hand loom may grow no more than 9 inches in a week.

space to consider the particular wool which finds its way from the factories of the wool merchants into those where worsted, that popular material from which suits are made, is manufactured.

An essential feature from the point of view of good worsted is the length of the wool. This, in fact, explains why some suits of clothes cost twenty guineas whilst others cost as little as five. The cheap suit consists of material made from very short pieces of wool; the more expensive has in its composition the longest, finest wool possible. A good way of testing a piece of material is to screw it up in the hands: if it springs open, creaseless, it proves that the wool it contains is of the best quality; for wool, like silk, has certain elastic characteristics. But if it is badly crumpled, this tells you that the wool in it is short.

Having sorted the raw wools into their respective grades, the worsted manufacturer subjects them to a process of combing, known as *carding*. This is to separate the fibres, which, despite the mechanisms through which they have passed, have knotted together. The machine responsible for carding consists of a series of rollers and strong steel teeth—very like the teeth of an ordinary hair comb.

The wool is fed between the rollers, and forced on to the teeth, which, gripping the wool, gently but firmly tear the fibres apart. The wool then passes on, through more rollers and across more combs meeting here and there with a specially-prepared oil whose purpose is to ease the process and preserve the texture of the fibres.

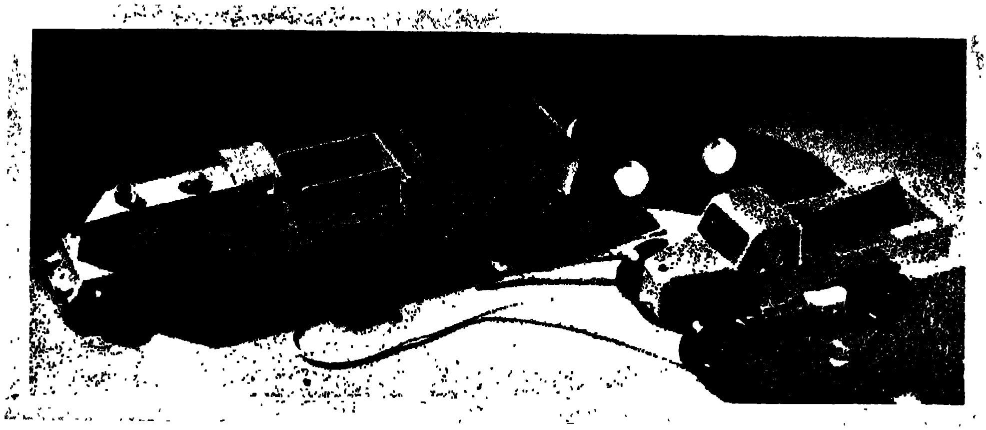
Next comes another washing, to rid the wool of the oil, then another combing—and, at long last, the machines give up fibres of every imaginable length and texture all ready for dyeing, spinning, and ultimate manufacture into suits to clothe mankind.

Mirror Features.

MECHANICAL WEAVING IN CARPET-MAKING

It is not only for the making of various articles of clothing that wool is used. Carpets are another type of woven fabric made with wool on foundations of various materials. Here we see two beginners learning the mysteries of mechanical weaving in a famous carpet factory at Wilton, Wiltshire. Carpets were made here in Elizabethan days and weaving machinery was introduced in comparatively recent times.

PLASTICS—A MODERN INDUSTRY



Chad Valley Co., Ltd.

MOULDED IN PLASTIC MATERIAL

Plastics are not by any means a new discovery, but within the past ten years a great many new plastics have been evolved. Certain kinds are particularly suitable for children's playthings and the toy train and motor lorry, seen in the picture above, are typical examples of the use of plastics in this field.

SOMETIMES, in the progress of world affairs, man seems to demand something more than nature can provide from her rich stock of timber, minerals and other raw materials. In such a case science often rises to the occasion, finding in its harvest of knowledge garnered through patient research a fruitful means of fulfilling man's requirements and giving to nature just a small measure of respite.

What we to-day call plastics for the want of a better word is an excellent example of such a happening, and there is every indication that in the future we are likely to depend more and more upon plastic products. At the same time, let us understand that we are not about to explore in this chapter an undeveloped field. For many years now we have had things made from plastics, and you have only to think of the flexible material with which photographic films are backed; of table-tennis balls, gramophone records and the fountain-pen barrel to recall some very important uses for various substances that fall within this group. Sealing wax is, by the way, a natural plastic product and there are seals in perfect condition now that were impressed upon documents long centuries ago.

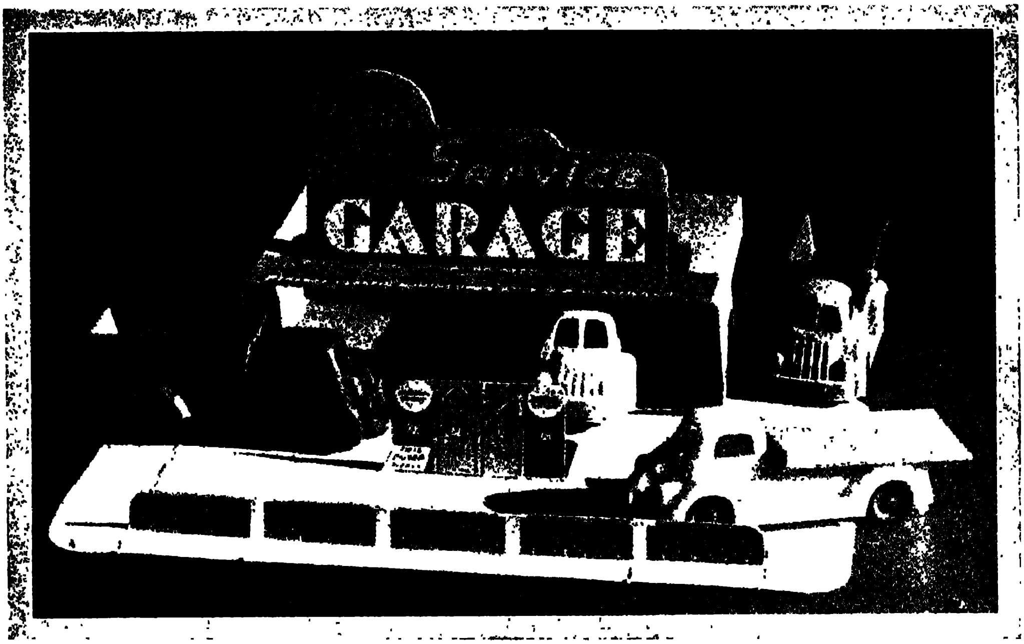
You will first of all wish to know what plastics are. They may perhaps best be described as a range of materials that in the course of manufacture can be rendered plastic or soft with heat and then moulded to the required shape under great pressure.

Strangely enough, modern plastics first came into being because there was a world shortage of ivory and the price of this natural commodity became too high for the commercial needs of the time. A scientist thereupon produced what we call celluloid by treating cotton cellulose (taken from the cells of cotton down) with an acid. You will know how valuable celluloid is. It is used for billiard balls, piano keys, handles of knives, combs and other articles, and was invented in 1868.

Discovered by Accident

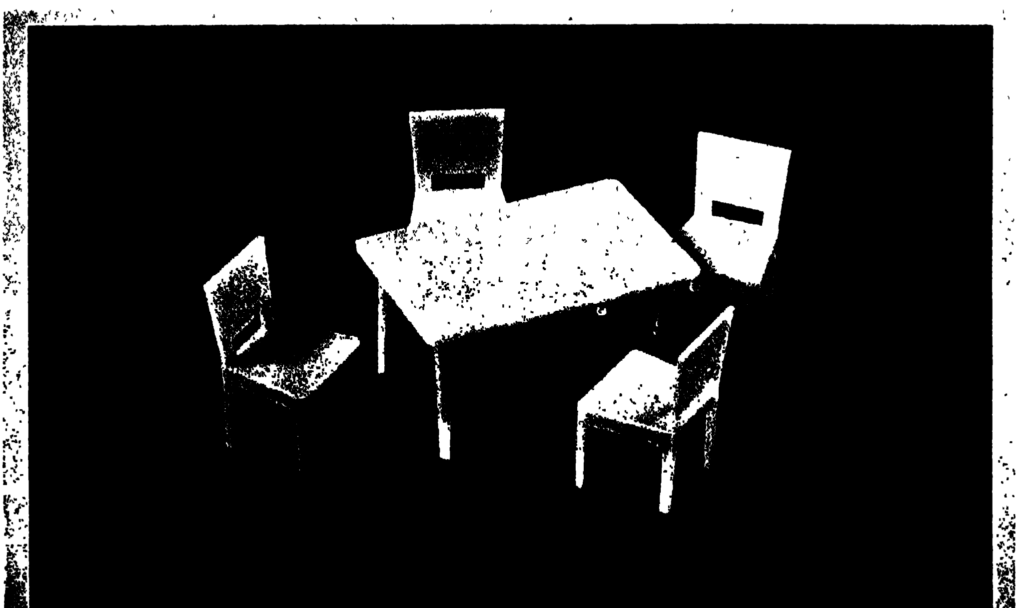
More than twenty years later another scientist discovered a second plastic called casein. It is said that he found out his valuable secret through mingling by accident in his laboratory some sour

A NEW GARAGE IS OPEN



E.V.B. Plastics Ltd

For the modern boy interested in motor-cars and everything connected with them the toy-makers have produced the roadside garage seen in the photograph above, complete with petrol pumps The cars and motor lorries are in various colours. For these the plastic material used is cellulose acetate.



Punfield & Barstow (Mouldings) Ltd.

Here we have another example of the use of plastics in the manufacture of toys for children. The table and four chairs seen above are light, practically unbreakable, and are made in a variety of different colours.

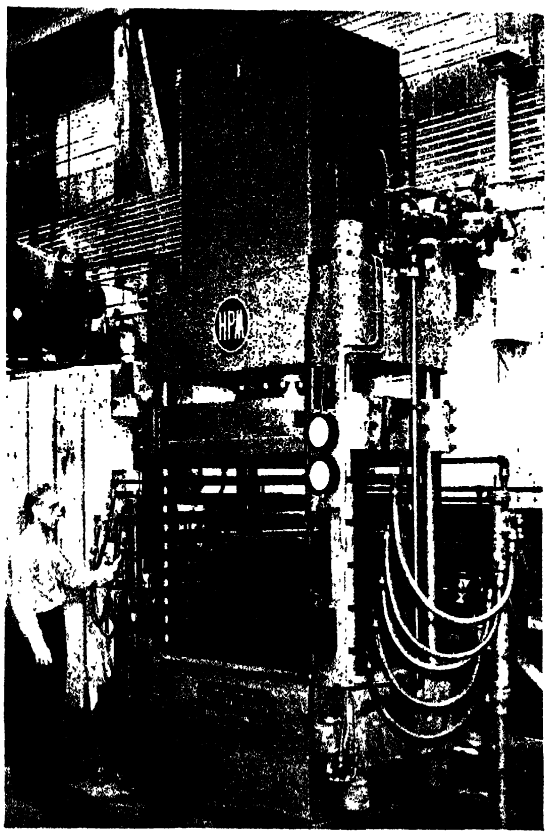
milk and a substance known as formalin and here was an artificial product to take the place of horn and possibly even of tortoiseshell, for both of which we had previously looked to nature. Later, camphor was used in connection with cellulose and so there arose xylonite, a plastic everyone will know.

We must go to America to follow up the next vital stage of development. Here, in 1909, Dr. Leo Hendrik Baekeland was busily conducting experiments in an effort to discover an artificial substance that would materially advance the science of plastics. He too used formalin or formaldehyde (largely produced from coal) in close combination with phenol (a product of coal tar) which he blended together in certain proportions under heat.

It was in this manner that there came into being one of the principal plastic materials, a man-made resin or resinoid which is known by the trade name Bakelite, a name that is now a household word in the realms of plastics all the world over.

You will all know natural resin, which is a kind of gum that comes from trees and plants. You may often have seen the stuff oozing from a plum or cherry tree in the garden and have noticed some of it in the house when prepared for commerce for floor-polishing and other domestic purposes. If you play the violin, you may have rubbed the hairs of your bow with a piece of refined resin, and the synthetic product can be seen in lumps of a dark amber hue, almost transparent and both hard and brittle.

Good Dr. Baekeland, after whom Bakelite is called, at first mixed his precious resinoid in small test tubes in his laboratory. It is now produced



Hydraulic Press Mnfg. Co.

A HOT PLATE PRESS FOR PLASTICS

In this picture we see one of the big presses used by the Plastic manufacturer. It is equipped with eleven steam plates, each measuring 44 inches by 40 inches by 2 inches, and is capable of squeezing the moulding material at a pressure of many tons.

United Ebonite & Lorival Ltd

PREPARED FOR A RAINY DAY

The use of plastics has been extended to many articles of wear and in this picture are seen examples of their use in the manufacture of waterproof coats These are very light to wear or carry yet proof against showers of heavy rainstorms The material in this case is P V C , which is a convenient abbreviation of the chemical name Polyvinyl Chloride

in whole batteries of large stills and the chemicals which feed them are stored in monstrous containers, each having a capacity of some thousands of gallons. The resinoid comes from the stills in a sluggish, treacle-like substance which hardens as it cools in giant trays having then an appearance not unlike that of barley sugar. Next, for the making of plastics, the resin has to be passed through a powerful crushing machine until it is converted into a powder as fine as flour.

At this stage, it will be well for us to understand that in the industry we are exploring together there are thermo-plastic and thermo-setting materials. The term thermo need not bother us at all, for it means merely something that has to do with heat. Thus, the former substances, of which celluloid is one example, can be softened by heat and hardened by cooling again and again and lose little or nothing in the process.

In the second group, however, the materials are moulded under heat and pressure and this brings about polymerisation. This is a long and perhaps puzzling word, but it means simply that chemical changes take place and the entire mass, however large or small it may be, becomes one substance that has set permanently.

Wood Flour for Filling

Having got thus far, it will be clear to you that the foundation of thermo-setting plastics is artificial resin, but this is not all by any means, for the resin itself would be much too brittle if used alone and none of the desired effect could be obtained. This resinoid requires what is called a filler and so there are mixed with it certain other commodities in powder form according to the purpose the finished article will be called upon to fulfil

Wood flour is such a filler and the name explains itself. Mica (a glass-like mineral) and the fibres of cellulose (obtained from plants) are other fillers,

and when asbestos is used we obtain a plastic that will resist a great deal of heat. As for the cellulose fibres, they serve almost to reinforce or strengthen, as do steel rods in concrete.

To explain the matter fully, when it has been reduced to a fine powder, the resinoid has the filler and such colouring matter as is required mixed with it and the mixture is fed in a continuous stream on to the heated rollers of a special appliance. The heat renders the whole matter plastic causing the resin to impregnate the filler and it leaves the rollers very much in the same form as would a sheet of crude rubber. It has then to pass, by means of a conveyor belt, to another crushing machine and thence through a sieve after which it is ready for the final process.

If you had the privilege of watching the making of moulded plastics you would stand in a room at a factory near an hydraulic press capable of exerting a squeeze of some 70 tons, though there are presses in use for exceptional purposes that can squeeze at 1,500 tons, and even more, whilst moulding pressure may be anything from 1,000 pounds to 4,500 pounds to the square inch of the material. On the base plate of this press you would see moulds of heavy steel, with the counterparts in the upper jaw, and you could detect for yourself if the press were heated by steam, gas or electricity.

The advance of plastics as a commodity of everyday use has brought into being a new and highly-skilled operative known as a moulder, and you will be able presently to watch him as he places in the bottom part of every mould a carefully measured quantity of the materials required.

The moulds themselves are hot before the powder goes into them and the press is brought down and left for a period that may be as much as fifteen minutes or less than one minute, according to the nature of the articles being made. Then, as the upper part of the press is raised, the completed items, whilst still hot, are ejected mechanically from the moulds.

United Ebonite [illegible]

IN WIDE VARIETY

It would be impossible to list all the articles in everyday use which are to-day made in plastics. Our photograph shows an interesting range of mouldings for various uses, most of which will be easily identified. Among them are: (1) Water testing box assembly; (8) Telephone mouthpiece; (18) Belting; and (24) Cigarette box and cover.

AEROPLANES, SHIPS AND CARS *Copyright.*

This is a small selection from a wide range of children's toys. All are made in plastic material with "Celastoid" Injection Moulding Powder. What colour is required is incorporated during the course of manufacture and is therefore permanent. The toys shown above were made by Cascelloid Ltd., Fraser and Glass Ltd., and Fairylite Ltd.

On the other hand, if you had been a fascinated spectator of the thermoplastic process, the material would have been put into cold moulds and left in them after the processing until they had given up all their heat. The highly-polished appearance in both classes of article is due entirely to the fact that the surface of the steel mould is perfectly burnished.

By Mass Production

What sort of articles are moulded in this way by the thermo-setting method? We can think at once of the standardised telephone instruments, the outside cases and inner component parts for radio sets, caps for bottles, camera cases, electric bell boxes, automatic lighters, trinket receptacles and so on. All such useful items are made on mass production lines in their hundreds or thousands and the high cost of steel moulds is amply justified.

It would not, however, be profitable to make such moulds for the casting of only a very small number of articles and we must never run away with the idea that plastics are necessarily cheap; actually, in many instances, they are only produced at very considerable expense.

There are plastics now to represent china, porcelain and even glass, most of the articles being produced by moulding, but other and equally valuable types reach the market without moulding at all. Thus, in the case of some sheets formed by the thermoplastic process, the material can afterwards be softened by heating and then finished in steel moulds or wooden

formers to make glass-like enclosures for aircraft, children's dolls, babies' rattles and so forth. Where a hollow article is being made it is moulded in two halves, steam being admitted to force the halves into the moulds, the edges needing merely to be welded. As a matter of fact, welding is a simple process with such plastics for whilst the edges are soft through heat they join readily together.

Yet another most useful form of plastic material is that known as laminated plastics. In this instance sheets of paper or of fabric are saturated with the artificial resin and allowed to dry. They are then assembled and arranged in a pack one sheet above another until there are sufficient to form a board of the required thickness. The laminated or built-up packs are next placed between burnished steel plates and subjected to heat and pressure, the result being a panel much stronger than one produced by moulding.

Such boards, up to 8 feet by 4 feet in area, are most effective when used for surfacing walls, forming table tops, counter tops, doors and even ceilings. They can be seen in the saloons and corridors of some of our crack railway trains and in the lounges on ocean liners, whilst as decorations to bathrooms they are ideal because no steam can affect them and a mere wiping down is sufficient to keep them clean. These laminated boards vary in thickness from that of a postcard to about 6 inches.

Moulding by Injection

Another process of great interest is

I.C.I. Ltd. (Plastics Division)

AS CLEAR AS GLASS BUT STRONGER

Among the more recently discovered of the many plastic materials now in use, Perspex has become most widely known owing to its use in aircraft. It is much lighter than glass, can be produced in sheets of various thickness and moulded into any desired shape under gentle heat.

I.C.I. Ltd.

CORRUGATED PERSPEX

Here we see a sheet of corrugated "Perspex" (methyl methacrylate) mainly used for factory top lights set in corrugated iron roofing. It has also been used successfully for partitions and screens in restaurants.

that known as injection moulding. Here the cold moulding powder in its appropriate mixture is fed into a hopper from which it passes to a heated cylinder where it quickly becomes fluid. It is then, by means of a piston, forced through a nozzle into a mould at a lower temperature so that the plastic hardens at once. Combs, frames for spectacles, ashtrays and even thimbles are made in this way and at a speed that seems almost impossible, the machinery employed being in the main automatic. Incidentally, in a thermo-setting ashtray, a lighted cigarette may be allowed to burn itself out and not leave the slightest mark.

There are several other processes in our new world of plastics, but sufficient has been written to give some idea of the vast field opened up by this artificial material, and we must all realise that in the future it is going to be still more important. We may even be approaching an age of plastics, for chemists are constantly finding new combinations of materials.

In Pastel Shades

Let us remember that almost any colour, including the pastel shades, may be incorporated into plastics in the course of manufacture so that no subsequent painting is required. If desired, as in the case of table tops and wall panels, an artist's design can be included as the moulding is fashioned and the resulting picture permanently protected by a film of resin. In our homes we may have plastic skirting boards and decorative wall tiles, whilst pipes and cisterns for the domestic water supply can be made of the same substance.

Varnishes, lacquers and cements are made from the resinoid and are available for innumerable uses, being applied by spraying, brushing or dipping. The varnish is excellent for insulating electrical fitments whilst the cement is employed for fitting the bulbs of

electric lamps into their sockets and many similar purposes.

The use of plastics for gear-wheels in machinery has recently come very much to the fore, largely because of the silence of such gears when in operation. Small gears can be moulded and it should be remembered that when a suitable base mixture is utilised plastic material can be drilled, turned on a lathe, planed, cut with a saw and shaped with a chisel, rasp or file as might be the case with ordinary wood. Moreover, a plastic substance can be faced with metal when such a step is necessary. Even the bearings of certain classes of machinery can be formed of plastics and bearings of laminated plastics are said to wear as well as those of bronze, water being frequently used as a lubricant. Further, the electro plating or spraying of bearings with metal is well within the range of the industry.

That we shall have plastic motor car bodies is a possibility. We already use plastic window frames, dashboards and instrument fascias in our cars and the day is perhaps not far distant when plastic coachwork will be a feature of such vehicles. So far as aeroplanes go, this type of material is extensively employed and reinforced panels for the fuselage have proved their worth, whilst plywood panels interleaved with resinoid instead of glue are noted for their strength and durability.

During the past ten years a great many new plastics have been discovered. Three of the most widely known of these are Perspex, P.V.C. and Nylon.

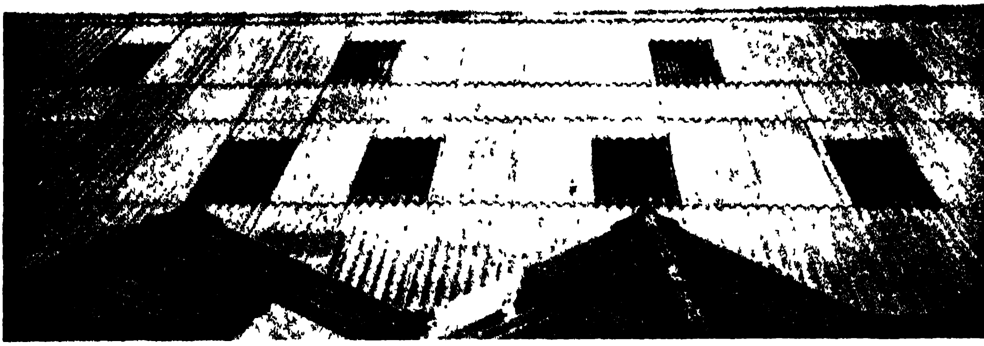
Perspex, the Glass-like Plastic

Perspex became most widely known owing to its use in aircraft. It is a substance which resembles glass in appearance, but it is very much lighter. Its chemical name is methyl methacrylate. It can be produced in sheets of various thicknesses and it has the interesting property that when sheets of Perspex are slightly warmed they become pliable, so that they can be moulded into any desired shape.

One of the most interesting applications of this material to peacetime uses is illustrated in the pictures shown in these pages. Here we see a section of corrugated Perspex suitable for use in the roof covering of a factory. This forms a skylight which is practically unbreakable.

P.V.C. in War and Peace

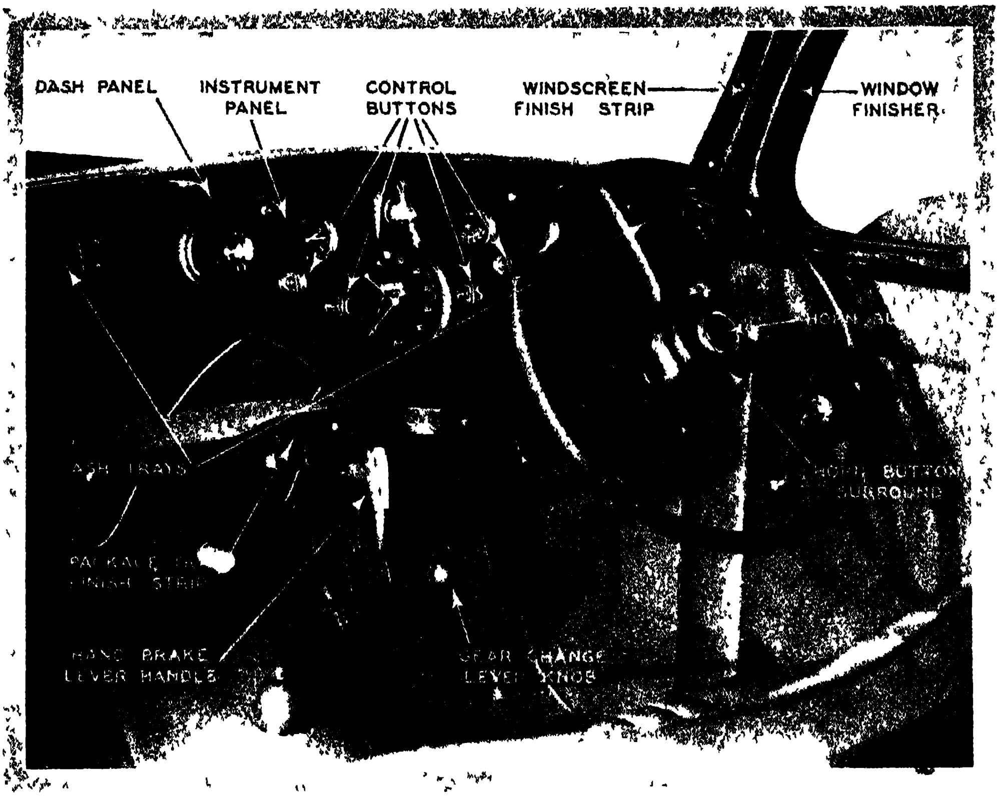
Here is an interesting story about



I.C.I. Ltd.

UNBREAKABLE TOP LIGHTS

In this photograph we see the "Perspex" sheets shown in the previous picture in actual use on the corrugated iron roof of a locomotive shed at a London station As it is practically unbreakable and easily fixed its advantages are obvious.



Ford Motor Co., Ltd.

FITTINGS FOR MOTOR-CARS

The motor-car manufacturers use a considerable number of fitments made in various kinds of plastic material In the photograph above some of these fittings are seen from the viewpoint of the driving-seat and their purpose is indicated The use of plastics in aeroplanes and cars is steadily expanding and the all-plastic car is a possibility of the future

P.V.C. These initials are an abbreviation of the chemical name Polyvinyl Chloride, a plastic made from hydrochloric acid and acetylene. This substance has properties very similar to those of India rubber. During the war, when our rubber supplies were cut off, manufacturers of electric cables and also rubber tyre manufacturers were faced with the problem of finding a substitute for the rubber which up to then had been considered indispensable for their products. P.V.C. proved to be the plastic which most nearly fulfilled their requirements. Many thousands of tons of P.V.C. were used by cable makers during the period of rubber scarcity.

The peace-time uses of P.V.C. are very varied. In addition to its use in the electrical industry it is used for chemical piping, and for lining tanks to protect them from corrosion. It has been made up into useful articles, such as tobacco pouches, braces, belts, wrist watch straps, and garters.

By passing the material through hot rollers it can be spread out into sheets and many beautiful colourings can be given to the material which can then be used for manufacturing waterproof garments, curtaining materials and so on.

Not the Cheapest, but the Best

Many people have the impression that plastics provide a cheap substitute

for other materials. This may have been true in the very early days of plastics when, for instance, white celluloid was often used as a substitute for ivory.

It is not true to-day The materials which are now being produced by plastics manufacturers are new materials which have properties not possessed by any materials used before For instance, laminated plastics are being very largely used for the panelling of rooms in public buildings and in luxury liners, such as the *Queen Elizabeth* and the *Queen Mary* These plastic materials were selected by the designers not because they were cheaper than other available materials, but because they were the very best materials available for the particular purpose in view

To take another example, Perspex was used during the war for pilots' windscreens, gun turrets and bomb-aiming windows not because it was the cheapest material available -glass is much cheaper but because it had properties not possessed by any other material known to science.

Nylon, the Wonderful Fibre

Nylon is another of the newer plastics which has become very widely known Nylon stockings are highly valued not because nylon is cheaper than silk or rayon (artificial silk), to which it provides an alternative, but because the nylon fibres have qualities which are not found in real silk or rayon These qualities provided the reason for the extensive use of nylon during the war. Parachutes, parachute cords and ropes for towing gliders were made of nylon fibres because these fibres possessed the requisite strength and resilience which were necessary for these particular applications The question of cost was a secondary consideration Weight for weight, nylon is stronger than steel

Since the war, nylon fibres have been applied to many other purposes For instance, tooth-brush bristles, hair-brush bristles and surgical sutures, *i e*, for sewing up wounds instead of the silk or cat-gut fibres which were previously used

One of the most important things about nylon, like many other plastics is that the raw materials from which it is made are very plentiful In order to make nylon, the plastics chemist takes salt, coal, water and air and by a complicated series of reactions he causes these substances to split up and to reform new combinations resulting finally in this wonderful new substance.

P B Cow & Co Ltd

GUARDING THE FORT

Toy soldiers have always been popular but the days when they were made of lead and tin are fading and plastics are being largely used nowadays The soldiers seen above are in khaki and were moulded in Polythene one of the new plastics

Plastics for Water-softening

One of the most surprising applications of plastics is in connection with water-softening. Certain plastics when suitably treated can be used in a water-softening plant, so that water passed through the water-softening equipment becomes for all practical purposes as good as distilled water, *i.e.*, free from any trace of "hardness." One type of this apparatus has a battery of water-softening tanks which use synthetic resins or plastics as a water-softening medium. An especially interesting feature of this method of water-softening is that the plastic reagent can be regenerated, that is, made as good as new, at intervals by treatment with a suitable acid.

British Industrial Plastics Ltd

A TOY HOUSE BUILT IN SECTIONS

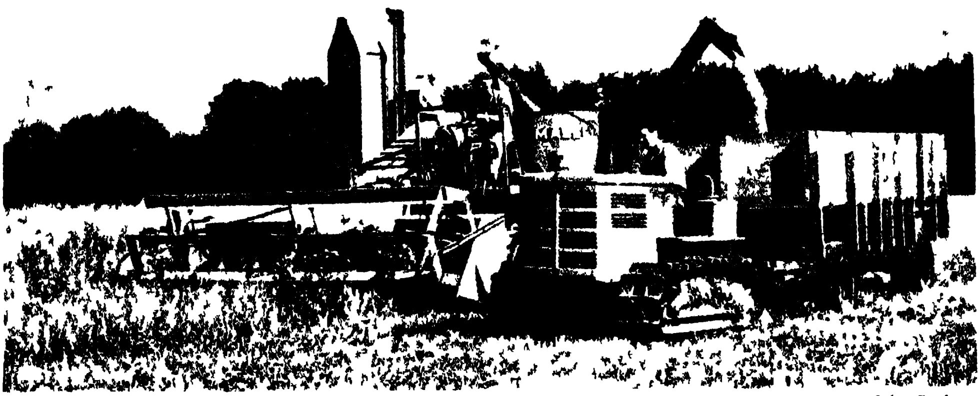
A doll's house has been a popular gift for children for many generations, and here we have one made of plastic material in sections so that the child can become a builder when fitting the different parts together.

Plastics from Sand

The very latest development in this field are silicone plastics. The basis of this new series of plastics is silica or sand. When sand is heated with coke in the presence of chlorine gas, a substance called silicon tetrachloride is formed. When this chemical is treated with a magnesium compound a new substance called chlorosilane is produced. From this a number of plastic materials can be produced by suitable chemical reactions.

Some of these plastic substances are liquid and can be used in place of insulating oil in electrical apparatus, whilst others are solid and have properties which render them of particular interest to electrical manufacturers who wish to obtain materials with good insulating properties. Such materials can be used by the electrical manufacturer to prevent the electric current from leaking away from the wires and other conductors which he uses on his electrical machines.

It is not possible yet to make plastics which are as strong as steel or which can be beaten into different shapes as copper can. But many qualities, such as resistance to moisture, transparency, lightness, colour, high electrical resistance, ability to withstand heat, can all be obtained by selecting the correct plastic and combining it with certain other substances known as fillers. For many purposes plastics are taking the place of metals and wood, and it is not an exaggeration to say that, in view of the developments taking place, we are at the beginning of a new era, the Plastics Age.



John Topham

THE FARMER'S BOY — MODERN VERSION

The old order changeth yielding place to new is is true on our farms as in any other sphere of industry The modern farmer s boy often knows more about machinery than horses In this picture a combine harvester is at work on an English farm It reaps threshes the ear pours the corn into the truck advancing alongside and bales the straw

THE FARMER'S BUSY YEAR

FARMING is one of our most vital industries upon which we depend for essential food Our milk and dairy produce, much of our meat, poultry and eggs, corn, fruit and beet for the making of sugar, come from our farms which, in England, Scotland and Wales, provide a livelihood for more than 1,250,000 men and women There can be very few other callings in which more workers find employment

Farms are not all alike Apart from the fact that some are small and others very large, they vary to a marked extent according to the locality, nature of the soil and available markets. An arable farm is one where much of the land is ploughed, a grass farm is one on which stockrearing is the main interest

To quote some examples, Wiltshire is a notable dairying county, because its climate is genial and it can produce crops of good grass and roots for the support of milking cows Devon is largely a shire of mixed farms, partly arable and partly pasture, where there are cows, bullocks (for beef), sheep and other livestock as well as cornfields and fruit orchards Downland country often with chalk beneath its thin top-soil, yields short grass on its dry hard ground, and this is ideal for flocks of sheep Because of its rich earth and the shelter of its many valleys the undulating county of Kent is famous for its fruit farms and hop gardens

This brief description might be continued almost indefinitely, for there are always sound geographical and climatic reasons for the presence of certain types of livestock and farming in one part of the country and not in another

Our Breeds of Cattle

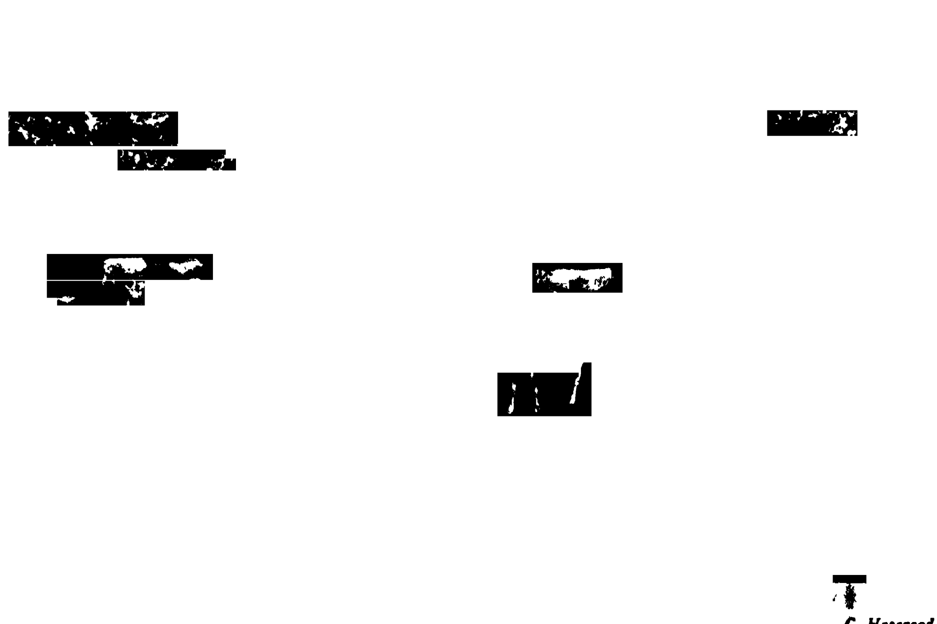
In the mountainous country of northern Scotland there is a breed of shaggy, long-horned animals that look almost wild These are the true Highland cattle, but, in the south-west of

Scotland you will find the Ayrshire breed, mostly brown and white. On the opposite side of Scotland there is the Aberdeen-Angus, black, hornless, and very hardy. Do you know the Herefords, which have white underparts and faces, the remainder of their coats often reddish in hue? Their name tells us the part of the country from which they come, and the breed is particularly good for beef.

Jersey and Guernsey cows, fawn coloured but with darker patches, are both famed for their yield of rich milk, and originated in the Channel Islands. The Shorthorn is found on farms all over the country, and this breed produces first-class milkers and large animals for beef. Devonshire cattle are mostly red in colour, and there is a hornless breed known as the Redpoll. Kerry and Dexter cows hail from Ireland. They are usually rather small, but particularly hardy and not in the least fastidious as to food. There are about twenty distinct breeds of cattle, and it is of interest to know them and be able to say from what part of the country they come.

To many people all sheep look more or less alike, but any sheep farmer can easily name a dozen and more breeds. Probably the most important are those that bear long wool, such as the Cotswold, Leicester, Wensleydale and so forth. The downland sheep, which include Southdowns, Suffolk and Dorset Horns, have shorter wool, and then there are the mountain sheep from which comes the finest mutton. In Scotland we may see the Cheviot and Blackface breeds. As you will know, the male sheep is a ram and the female a ewe.

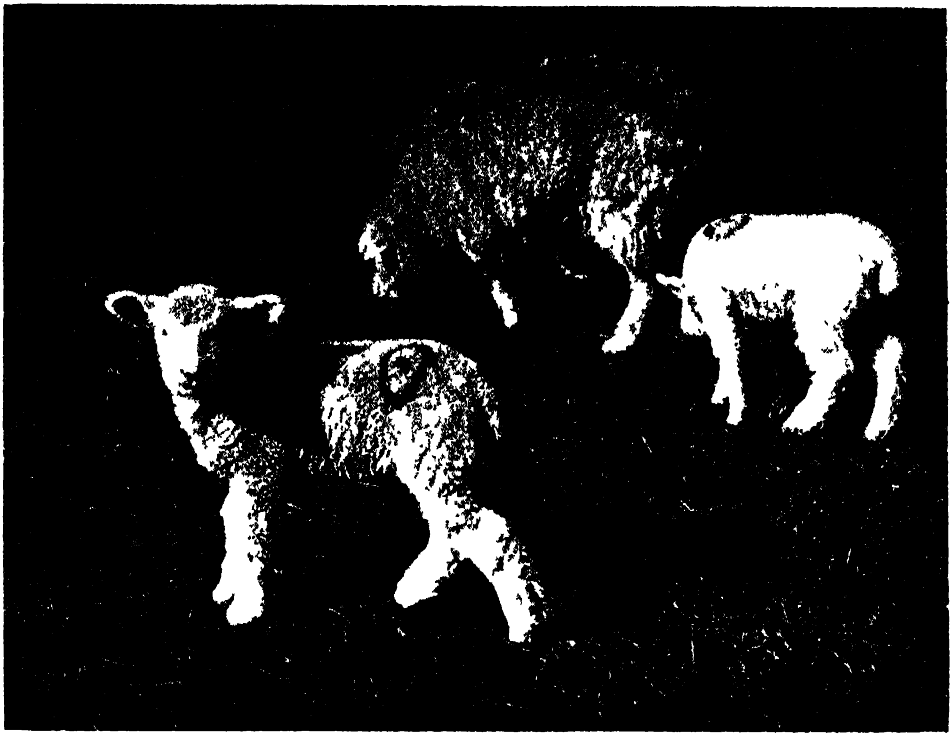
Our domesticated pigs, which give us pork, bacon, lard and many other products, probably all came from the wildlings that once roamed in the forests of this country. From these have been evolved ten or a dozen separate breeds, each associated with a particular district. Thus, there are the Berkshire breed (black); the Gloucester Old Spot; Lincolnshire Curly



C. Hosegood.

A FINE HERD OF JERSEY COWS

Jersey and Guernsey cows both originated in the Channel Islands, and each is noted for its high yield of rich milk. Jerseys are patient, docile animals and are usually fawn in colour with darker patches. In this country there are about twenty distinct breeds of cattle.



Harold Burdekin

THE SHEEP WITH TWO LAMBS

Though all sheep may at a casual glance appear alike at least a dozen distinct breeds are kept in this country. Those bearing long wool, like the ewe and lambs here illustrated, constitute the most important breeds, but the shorter woolled downland sheep are much esteemed. The best mutton comes from mountain sheep.

Coat with reddish hair; the Tamworth, which calls to mind the wild boar; Large Whites, Middle Whites and others. Wherever you see one individual breed in large numbers you may be sure that it is specially suited to the locality. Male and female are called boar and sow respectively; and, instead of saying a sow gives birth to a litter of young, we say that she is farrowing. All round the sty is a low farrowing rail beneath which the little ones can take shelter so that their mother does not crush them when she lies down.

Seven Days a Week

Horses, of course, form an important group of livestock on most farms, and we can read about them in our Natural History section. All we need note here about the horses is that they will be of the strong, sturdy breeds, such as the Suffolk Punch, well able to help in the work of the farm. For while more and more machinery is being used on the farm, there is still work for which the farmer is glad to have horses. Then there are the geese, ducks, turkeys, cocks and hens and often guinea fowl and bantams. Perhaps a nanny-goat or two are kept for their delicious milk; and, very likely, bees, which fertilise fruit blossom and cause the orchards to bear better crops. There may be a donkey and possibly rabbits, whilst you will assuredly find sheepdogs and cow-dogs, both highly trained, and plenty of cats for catching vermin in barns and such places.

From all this you will see what a wealth of real interest there is about a farm. Not only must a farmer attend to his livestock regularly seven days a week, but he must milk his cows and goats twice every day at the same fixed times. He has to grow as much foodstuff as he possibly can for his stock, besides arranging for the sowing, tending and harvesting of a wide range of crops. At no time is farm work ever finished, and we shall see as we pass through the seasons that the farmer is a very busy man indeed, and one who must always be looking ahead and making very careful plans for the future. And in no other calling does the master man need to have such a fund of practical knowledge about so many diverse subjects.

SPRING

The coming of spring, when there is white blossom on the blackthorn and catkins sway in the wind from every hazel, is the time when the plough is brought out so that the ground may be turned and made ready for seed-sowing There is in front of a plough a part called the coulter, which makes the first cut in the soil. Just behind it comes the share, which broadens the cut, carrying it several inches below the surface. Behind the share is the breast or mould-board of cast-iron, which quickly becomes polished with use, its purpose being to turn over the soil in the form of a continuous ridge. Usually on a plough for single furrows there is only one wheel.

Ploughing admits air and sunshine so that the good earth may be dried and sweetened after winter's rain. The implement may be drawn slowly but purposefully by a pair of willing horses or by three if the field is hilly The ploughman walks behind, guiding the share and driving the horses so that every furrow (*i.e.*, the space between the ridges) shall be straight and of even depth from one end of the long row to the other.

On many farms today we find that horses are not called in at all at ploughing time. Instead, there are tractors propelled by internal combustion engines, the ploughman occupying a

Harold Burdekin

FEEDING TIME WITH THE PIGS

We have ten or a dozen separate breeds of pigs, some varieties associated with particular parts of the country. The young pigs seen above have not long left their mother.

seat just behind the power unit. He may plough three or four furrows at a time, and an acre of ground can be turned over in about one-and-a-half hours. In these times, when more and more agricultural work is carried out by mechanical means, the farmer has himself to possess an ever-increasing knowledge of machinery.

Topical

A LAMB AND ITS NURSE

In this picture, taken on a Northamptonshire farm, a lamb, one of triplets, is being bottle fed by the shepherd to ensure that the ewe does not lose her offspring

The winds that come to us in spring, breezes that raise what every farmer calls priceless March dust, soon dry out the top crust of ploughed ground ; and, when the earth is in the right condition, it must be harrowed so that the rough ridges are broken down into a tilth fine enough to receive seed. This work may be carried out with a cultivator having many steel tines that pulverise the clods, the appliance being drawn by one or two horses. On the other hand, the land may be worked over with a disc harrow dragged to and fro by a tractor. The discs are saucer-shaped, at least as large as dinner plates, and their purpose is to cut up the lumps and level off both the ridges and the furrows. We rake our garden beds and borders to prepare for seed sowing and the farmer harrows with much the same end in view. He may indeed have to harrow several times before he is thoroughly satisfied.

Sowing the Seed

The next step is to sow the seed, and this is done with the aid of a machine called a drill that may be pulled slowly by a horse backwards and forwards across a field. In some cases two or even three drills may be hauled simultaneously by a tractor, each drill having a sequence of coulters or steel fingers for making the furrows, these being closely followed by spouts through which the seed dribbles at a rate that can be regulated. Oats and barley and often wheat are sown in this way in the spring, the seed to be afterwards covered in with a harrow ; and you will soon see how the long lines of green shoots come spearing through, at which stage a roller must be used to firm the soil round the roots.

Spring too is a period when potatoes are planted, this crop being specially

important on so many siltland farms in Lincolnshire and in the Perthshire and Dunbar districts of Scotland. Furrows are made with a double breast or mouldboard plough and along these gulleys the seed tubers are planted at even distances by hand, to be afterwards covered with a further turn of the plough. So that there may be more bountiful crops of hay, meadowland must be harrowed, often with bundles of brushwood tied to a beam (called a bush harrow) to tear out old dead grass, and then rolled. With the barley, clover is sometimes sown, and the short stiff stems of the cereal give protection to the undercrop. On some farms there may be turnips and other roots, as well as kale to sow to yield food for the stock in autumn and winter.

So much for the land, but there is plenty going on besides cultivating and sowing. There is lambing, for example, usually in full swing in March, though it begins much earlier than this in some southern counties. This is the busiest time of year for the shepherd, and he will take his hut out into the fields, prepared to sleep in it on many a night — if he can get time for much sleep at all Near the hut he will build a pen or fold of hurdles, their staves interlaced with straw, bracken or furze, to give shelter to the ewes and tiny lambs He will have special titbits of food for the mothers; and, if a ewe should die, he feeds the lamb from a bottle with tepid cow's milk. The sheepdog, too, will be having a busy time

So far as the stock sheep go, they are probably penned by means of hurdles on to portions of fields that are cropped with swedes or turnips, kale or other greenstuff As the animals eat this food right down to soil level, their droppings enrich the ground for the crop that is to follow. Thus, day by day, the shepherd advances his flock until all the available provender has been cleared.

Harold Burdekin

TWO PROFITABLE NANNY GOATS

Male and female goats are known respectively as billies and nannies and form profitable livestock on some farms. Goats' milk is very rich and especially good for infants and invalids.

When Cows Get Playful

Presently the cows, which have spent the dark months in their byres, shippons or sheds, living on chopped roots

John Topham.

PREPARING FOR SOWING BETWEEN YOUNG TREES

A long term policy is necessary in the growing of fruit. Here we see a newly-planted orchard of Laxton, Cox and Worcester apples. The ground between the rows of young trees is being ploughed with the aid of a tractor and ridge roll so that it may be used for other crops such as grass or lettuces, or it may be that gooseberry bushes will be planted here.

and greenstuff, cattle cake, chaff, hay, and so forth, will be let out to graze upon the new spring grass. What excitement there will be, what racing to and fro with outstretched tails, what slipping and slithering as the stock gets its liberty again in the green fields.

Filling the Incubator

Meanwhile, this is the poultry breeding season. Carefully selected eggs—certainly hundreds and maybe even thousands of them—have to be gently placed in an incubator and looked after in a steady temperature for twenty-one days. When the chicks appear a warmed brooder must be waiting for them because they have no feathered mother to attend to their upbringing.

Thus, as spring gradually unfolds, other events are taking place. The hedgerows are chitting into leaf and birds pairing. It is likely that one of the mares about the farm will have her long-legged foal and the little animal may be almost as playful as a kitten and often need correcting by its mother. Nowadays, when we obtain so much of our sugar from the white-rooted sugar beet, there will be seed to sow on farms where the soil is suited to this valuable crop. As spring draws on the horses, the cows and even the calves can once more sleep out in the fields.

That land which the sheep cleared so thoroughly must be re-sown, but with a different crop from the one before it. When a farmer speaks of the rotation of crops he means that he does not sow one subject twice running on the same plot of ground and this is most important because each crop has its own need in foodstuff, and it would be useless to sow where such food is temporarily exhausted. Then, if crops are growing well, there are bound to be weeds and hoeing must be carried out. In the fields, where cultivated plants are

always set at the correct distances, one horse will draw a hoe backwards and forwards whilst farm hands single out any seedlings that are appearing too thickly. It is all very like kitchen gardening on an extended scale.

The very late spring may witness the beginning of sheep-shearing when the wool is taken from the animals by a machine or by shears that work on the same lines as scissors. The wool from a sheep is known as a fleece, and it is made up into a bundle, perhaps with hundreds of others, to be taken away for sale.

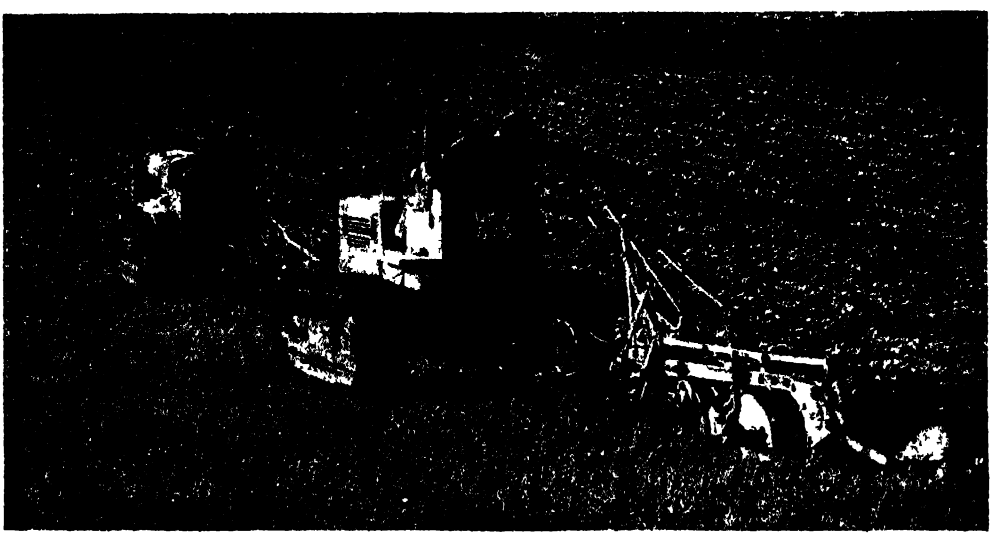
SUMMER

What is your outstanding recollection of a farm in early summer? You may visualise the great range of greens in the different crops, some of them appearing in serried lines, but what will most probably first come to your mind is a hayfield, and the object of cutting ripe grass and converting it into hay is to provide foodstuff for the stock when grass is not only very scarce but also possesses little nourishment. The farmer wants long, sunny days for cutting and drying his grass, and such days usually come during the last fortnight in June. In these hurried times grass is cut with a mowing machine; but, in your grandfather's early years, the work was done entirely by men wielding scythes, and the whetting or sharpening of the blade with a stone was one of the characteristic sounds of the countryside, like the blacksmith hammering a horseshoe on his anvil.

A mowing machine may be drawn by two or even three horses, or by a tractor, and as the blade clatters to and fro there is left behind a long neat row of cut grass which is known as a swath, not swathe. On some large and very up-to-date farms mechanical driers are used for conditioning the grass and then there is no occasion for further operations in the field, whilst the farmer need not worry in the least if the weather breaks and brings a deluge of rain.

Windrows and Haycocks

On the majority of farms, however, driers are not available and so a rake, drawn by a horse, tractor, or even an

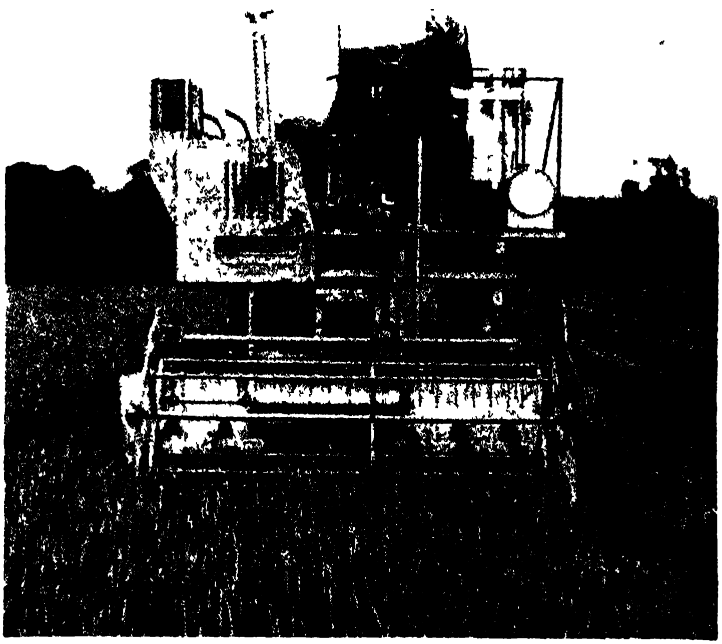


John Topham.

HEAVY WORK ON THE LAND

Two heavy "crawlers" are seen here at work on land which has grown oats in the past season. Now the crawlers are deep ploughing the field in preparation for the sowing of potatoes. Usually the crops follow each other in the order oats, potatoes, wheat, turnips or swedes, barley, hay, though this may be varied according to the location of the farm.

old motor car, gathers the swaths together into a long mound known as a windrow and from this the grass is on many farms put up into haycocks. These are just little heaps through which the wind may blow to dry the stems, a process that will require perhaps three or four days for its completion. Next, the hay is shaken up and spread out again, formed afresh into windrows and then gathered together in waggons to be built into ricks. Here it should be noted that one usually speaks of a hayrick, but of a stack of straw or corn.



John Topham

GETTING IN THE HARVEST

In this photograph is seen a remarkable machine known as the Grain Marshall at work on a field of barley which has been badly beaten by heavy rain storms. It is fitted with a special attachment for short-growing straw. The Grain Marshall does much the same work as the combine harvester.

Hay Must be Dry

Into the very modern hayfield, however, many new helpers have made their way in recent years. There is the sweep, an appliance that has a platform formed of long strips of wood thrust forward like so many fingers. Drawn by a tractor or ancient car it literally sweeps up hay; and, when fully charged, the ends of the fingers can be raised and the consignment taken direct to the rick. There is also the elevator, worked by a horse or small engine, which forms a sort of spiked escalator from ground level to the top of the rick. Such an implement saves a lot of human labour in tossing up hay with a long-handled hayfork. It should be understood, also, that hay must not be put into a rick until it is reasonably dry. If too wet it may heat.

About a month afterwards the thatcher appears to put a roof on the hayrick, which will by now have settled slightly. The thatch itself is formed of good wheaten straws all lying the same way and packed into bundles, and a start is always made at the bottom so that the second strip or layer can overlap the first, just as do the tiles or slates on a roof. To hold down the straw the thatcher, with his mallet, drives in spars cut from nut bushes or hazels, and connects them where necessary with lengths of stout twine or strips of straw rope.

When he reaches the top he makes a comb of straw to throw off the rain on either side, having first laid dollies or bundles of rough-dried herbage to form the pointed ridge. The comb he may decorate with fanciful ornaments made of straw, according to the custom of the county, and he may strengthen with heavy cord, chains or even a baulk of

Harold Burdekin.

THERE'S JOY IN THE HARVEST

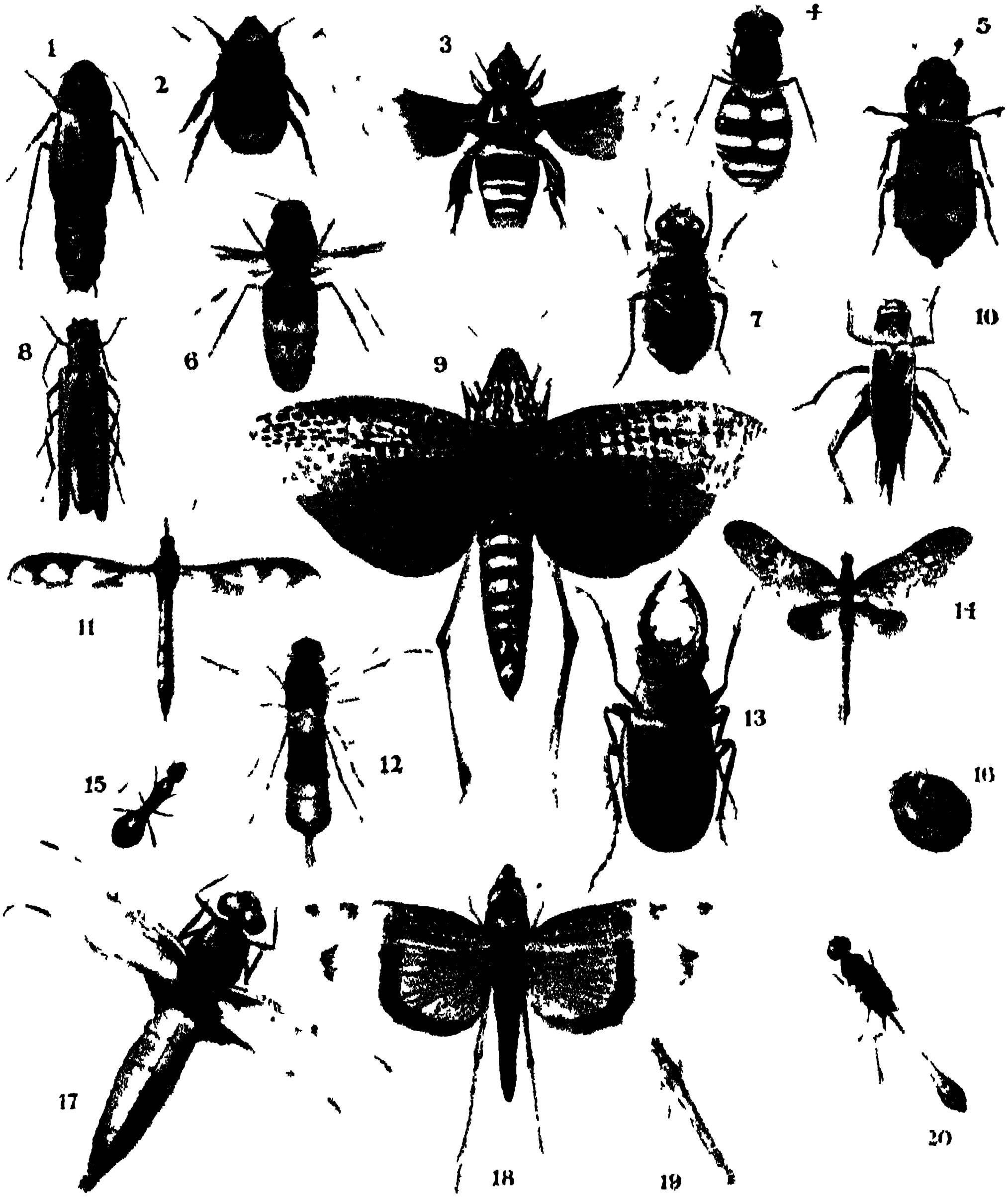
Harvest marks a busy time of year on a farm, but also one of the most enjoyable. Here a self-binder reaping machine is being drawn through the golden corn by three horses, and you can see how the sheaves are bunched together, tied at the waist and then tossed aside on to the stubbles.

wood an exposed corner where the thatch might be torn adrift by gales.

Following haymaking, there may be lambs and ewes to sell. The shepherd will have got the animals ready and probably put coloured marks on their backs to indicate their age. At the fair the creatures will be parted up into small pens, to the discord of much bleating, and the sale will probably be by auction.

BERRIES AND FRUITS OF THE COUNTRYSIDE

A wonderful variety of berries and fruits appears on the different trees and shrubs of the British countryside. Some of the fruits commonly known as berries do not strictly speaking come within that classification as only those in which the seeds are immersed in pulp are termed berries by the botanist. In the Plate are seen some of the different berries and fruits which are commonly found in many parts of Britain: 1, Holly; 2, Sloe (the fruit of the Blackthorn shrub and related to the bullace and wild plum); 3, Dog Rose (the crimson fruit is shown as generally known as the hip); 4, Bramble or Blackberry; 5, Sycamore; 6, Wayfaring Tree; 7, Horse Chestnut; 8, Hawthorn; 9, Black Bryony (the fruit is green, then orange, and red when ripe); 10, Dogwood; 11, Beech; 12, Hazel; 13, Yew.



SOME MEMBERS OF THE INSECT FAMILY

LAST LOAD HOME

Haymaking time brings fragrance to the air, but it is hard work loading from haycocks or windrows, and the farmer is pleased to have got the last load in the yield of a large field

Generally speaking, our crops of corn are cut with a machine known as a self-binder, drawn by two, three or four horses or a tractor. As it is cut, a bundle of corn falls on to a slatted platform. A canvas fitment compresses the bundle tightly, and it is then automatically tied with twine round the middle and flung out so that it lies on the ground in the wake of the machine. It is most fascinating to watch the sheaves dropping in rapid

Cutting the Corn

By this time, there is almost sure to be a marked change in the colour of the cornfields. Slowly at first, and then more rapidly green will turn to yellow and afterwards to the rich golden brown that is the signal for harvesting to begin. On very large farms, where there is ample capital for such costly tackle, a combined appliance is now employed which can deal with wheat, barley and oats when the crop is dead ripe.

It can cut the corn, thresh it, lay aside the straw and put the grain into bags right on the field. Naturally, such a machine minimises the risks of bad weather, and it also saves the cost of many intermediate operations. It is a system brought to us from the boundless prairielands of Canada and the vast wheatfields of Australia, and it would function best on our very biggest farms. Even then, in doubtful weather, the corn might have to be dried by artificial means

Photos: Featurephots Ltd

THE MECHANICAL ELEVATOR

Where hay used to be pitched from the waggon by long handled forks, elevators not unlike escalators are now used on many farms. The power may be provided by a horse or a small motor

sequence as the self-binder proceeds round and round the field, always driving the frightened rabbits towards the centre where many of them will be shot as the last swath is finished.

Behind the self-binder there follow two or three farmhands whose duty it is to build up the sheaves into stooks, four or five pairs of sheaves standing on their butts with the ears of corn uppermost usually forming a stook. Generally speaking, the sheaves remain in stook from a week to a fortnight, oats invariably taking the longest time to dry. There follows next the carting of the sheaves to the barton or stackyard where they are built into stacks that must, after slight settlement, be thatched

We call the short stumps of corn after it has been cut stubble, and pullets (*i.e.*, young hens) and other poultry are often placed on stubble fields to eat up such grain as has fallen from the ear. Roosting in portable sheds, a spell of this kind is like a holiday for the birds and strengthens them against the coming of winter.

Then, just when summer is waning, there will be potatoes to harvest and a wonderful machine with fingers on the outside of a revolving wheel will turn the tubers out of the soil ridges and leave them on the ground all ready to be picked up, perhaps by school-children. Ploughing will begin again on the fields of golden stubble, and there may be areas of ripe clover to cut and deal with as one would do with hay in June. Further, the end of summer brings with it Harvest Home and the close of the agricultural year. If a farmer is going to move to a fresh holding he makes the change round about Michaelmas, and can then commence a new life in a new home as October comes in.

AUTUMN

With the garnering in of the harvest and the shortening days the entire outlook of a farmer alters again. Before long now cows will have to be brought in from the fields to spend at any rate the nights in their byres. Drifts of smoke in the fields will indicate where

John Topham

A PORTABLE GRASS-DRYING MACHINE

One of the problems which always faces the British farmer is how to overcome the vagaries of our climate Sunny days are needed at haymaking time A spell of wet weather may ruin or endanger the crop Here is a drying and baling plant which tours the farms and deals quickly and efficiently with the mown grass on which the sun has failed to shine Three weeks' work can be done in three days

Harold Burdekin.

WITH THE THRESHING GANG

At threshing time corn stacks are taken down and the sheaves thrown into a revolving drum so that the corn can be removed from the ear and all weed seed and foreign matter left behind. Fine, dry weather is wanted to make threshing successful, and rat-hunts always add excitement to this dusty autumn task.

hedgeparings and the roots of coarse weeds are being burned on bonfires. Mangolds and turnips will have to be lifted and stored in a long deep trench known as a clamp and covered with earth through the ridge of which wisps of straw will form vent-holes. Potatoes will also have to be clamped.

Their Winter Sleep

The swallows and other migratory birds will all have gone, and soon dormice, hedgehogs, squirrels and similar animals will have begun to hibernate. Apple storing and cider making are autumn tasks, and this is the time when the roots of sugar beet are lifted and sent off to the factory for processing. Sheep will be folded on a crop that has been grown for them and some of the store cattle, still out in the fields, may need to have their meagre herbage supplemented with other food, such as roots and hay, that must be taken to them. In the barn the chaff machine will be whirring for long hours cutting up the immense quantities of food which stalled cows require, and something for the horses.

With cows in mind, it may here be mentioned that on many a farm milking is now done exclusively by machinery. The necessary suction through vacuum pipes is often obtained by means of a small gas engine. Thus, well-padded cups are attached to the cow; and, when suction is applied, the milk flows from the patient animal through spotlessly clean tubes to the cooler in the dairy, from which it may be filled

direct into bottles for retail customers. So long as the bin in front of her contains some tasty snack, a cow does not object to the milking machine, one man and a boy being sufficient to deal with a herd of fifty cows.

And did you realise that October, with all the glorious tints of autumn reflected in trees and hedgerows, is the right time for sowing wheat? The month is good for ploughing and cultivating, whilst autumn-sown wheat yields better crops than that sown in spring. This vital grain crop will probably be accommodated on land that grew roots during the summer, and if farmyard manure or artificial fertilisers are needed, they can be spread before the ploughshare begins its work. Most likely the farmer owns a special machine for the even distribution over the land of lime and fertiliser.

Probably, too, the threshing outfit, with its team of workers, will come noisily up the lane, a mysterious train of intricate mechanisms drawn by a steam traction-engine. When everything is ready, the day being fine and bright, off will come the thatch from the chosen rick directly there is sufficient morning light for work, and soon the sheaves we saw in stook in the harvest field will come tumbling downwards.

Baling the Straw

The purpose of threshing is to get the corn from the ear to the exclusion of weed seed and all foreign matter. This is carried out in a revolving drum into which the sheaves, when the string ties have been cut, are placed. Blasts of air remove the chaff or winnowings; and the grain, after passing through sieves, flows from a spout direct into bags ready to be taken away. Meanwhile, some of the farmhands may start building the loose, discarded straw into a fresh stack or passing it into an appliance that compresses it to form tight oblong bales.

If we count October as the first month of autumn, it certainly brings full days to the life of every farmer. November has fewer daylight hours, but wheat-sowing may continue if conditions are favourable and so may ploughing. Fruit orchards require pruning, and then the trees can be sprayed to keep down insect pests. Hay will certainly have to be cut from one of the new ricks and most likely some of the clamps must be opened to provide root food for the stock.

Fox Photos

LEARNING AN OLD-WORLD ART

There is much to learn before one can thatch a hayrick or cornstack, and above we see an experienced hand explaining the essential parts of the task to some enthusiastic newcomers

WINTER

When Jack Frost has made the land

A FARM OF OLD ENGLAND

Sport and General

Here is a typical farm of an English countryside --rolling fields to the uplands, a well-wooded section and then the farm itself with its outbuildings and stackyard. ' This farmstead is in Buckinghamshire, but similar holdings may be found all over the country, replete with their cattle, sheep, horses and poultry. More than 1,250,000 men and women earn their living from agriculture in England, Scotland and Wales

iron hard, ploughing and seed-sowing cease, but this is the most favourable condition for carting manure on to the fields, dumping it in heaps and then spreading it evenly. The going for horses or tractor will be good, because the wheels of the vehicles cannot sink into the ground. Snow, of course, stops all outdoor work, but on every farm there are animals to be fed, so that the food has somehow to be brought in, and, of course, cows have still to be milked. Further, a spell of snow gives anxiety to the shepherd.

Shaping Hazel Spars

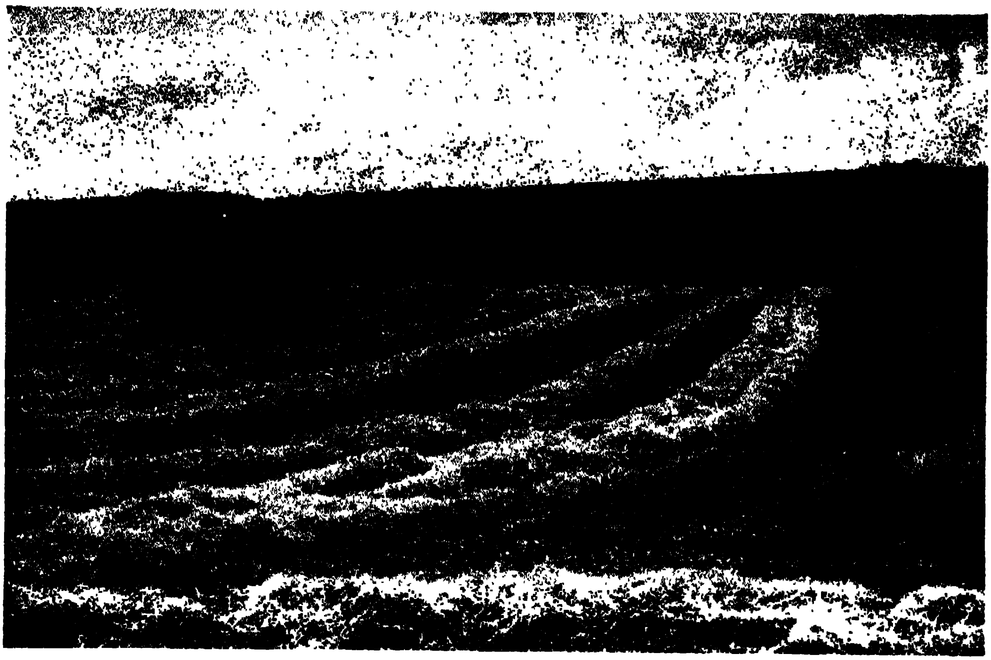
Many tasks of autumn and also of spring may be undertaken in winter, but very wet days will, like snow, bring a cessation to outdoor work, in spite of the rubber boots which modern farmhands wear. There are, however, numerous under-cover tasks apart from chaff cutting. For instance, the bundles of thatch for roofing hayricks are often prepared in winter, and so are hazel spars. Some of the expensive machinery about the place may need cleaning or overhauling. There are almost certain to be some hurdles to make, or perhaps a supply of new oak fencing posts needs to be put ready, with fir rails to match.

Wherever one finds livestock there is sure to be work to be done every day at all seasons, and winter's daylight hours are often not long enough for the many tasks that have to be carried out. Winter, too, is but the gateway to spring, and we have seen already how busy the farmer is then. But for those of us who are town

Eric Guy.

IN THE STACK YARD

At harvest home on many farms the produce of the cornfields is gathered together in the barton or stack yard where it may be found ready to hand by the threshers. To complete the stacks there is important work for the thatchers, as a good bonnet of straw will keep out autumn rains and winter's snow.



Topical Press.

A WILTSHIRE BARLEY HARVEST

These beautiful farmlands are near Fonthill Bishop, in Wiltshire. Their rich harvest of early maturing barley is being harvested by three combine-harvesters which, while they are not so picturesque as older harvesting methods, are much more efficient and economical for Britain's larger farms. Such machines make us think of the vast wheatlands of Canada and Australia where they are in much more common use.

dwellers, winter is not the best time for a visit to the country. Summer, and especially harvest-time, is when we shall see the fields and the farms in their full glory, although Spring, when everything is awakening from its long winter sleep, is one of the most beautiful seasons of the year in the British countryside.

Life in the Country

Many who live in towns envy the farmer his healthy, open-air life, and when summer comes there is nothing that has a greater appeal than to escape from the dust and bustle of the city to the countryside where the freedom of the meadows can be enjoyed and the sweet-scented air of the woods and hedgerows can be breathed.

Some of us, perhaps, may take an inexpensive holiday by working on a farm at harvest-time, or join a harvest camp. At this time of the year the farmer is glad of all the help he can get and in recent years many thousands of town-dwellers have for a brief spell become farm workers, with benefit to themselves and the farmer. Harvesting is hard work and there is a great deal to be done. But those who spend a holiday in this way experience the joys of the countryside and learn more of the wonders of Nature in a way that only farm life and the countryman can teach. How much there is for the town-dweller to see—and how much there is for him to discover in the countryside! A completely new world is revealed to him, a world that becomes increasingly fascinating as he learns from the farmer and the workers of the countryside, as well as from his own observation, about the living things in the fields and of the secret life that goes on in the leafy lanes and hedgerows.

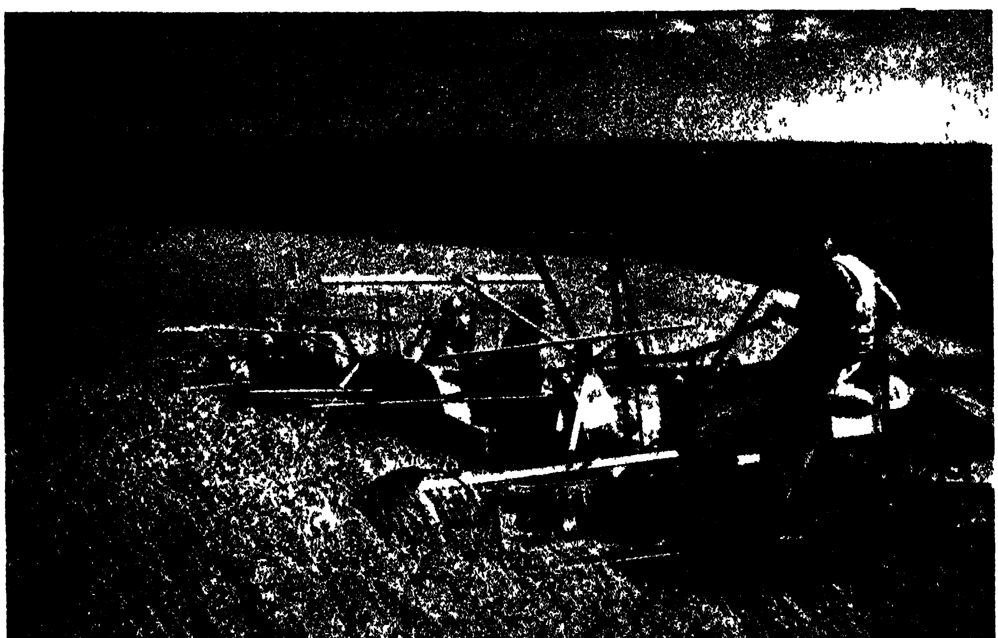
In the fields, down the lanes, along the hedgerows, and beside the ponds and streams are to be found all the wonderful bird, animal, plant and insect life of which at normal times the city-dweller can only read. Besides the larger inhabitants of Nature's kingdom in the countryside there are smaller, but no less wonderful creatures which play their part, for good or ill, on the farmlands. There is the bee, which not only provides honey but pollinates the farmer's fruit trees; the ladybird, a familiar visitor perhaps to our town gardens, which destroys the insect pests on the apple trees; and the worms whose ceaseless activities help the farmer since they loosen the soil.

There are some who are counted among the farmer's enemies: the click beetle, the crane fly and the white butterfly In mentioning these well-known creatures we only touch the fringe of the amazing world which can be explored in the countryside.

In the Woods and Hedgerows

We all know how the face of the countryside changes with the seasons: Spring brings the fresh green of new life to the woods and hedges; Summer brings the flowers and their sweet scent, while Autumn decks the trees in tints of brown and gold and loads the trees' branches with autumn fruits and berries. Most of us have probably been blackberrying at some time or other and know the bramble, or blackberry, as well as we know another berry, the holly, which decorates our homes at Christmas time. We may know, too, the fruit of the sycamore tree which is borne to earth on small wings, and the horse chestnut, which, robbed of its spiky, green outer casing, is used for the game of "conkers."

But there are many more fruits and berries than these to be found in the woods and hedgerows. Some are used for making jelly and cordials, or in pies and tarts. Others are poisonous, but



Keystone

REAPING IN THE MODERN MANNER

Farming is not only a man's job these days, and these Land Army girls certainly seem to be enjoying their task of reaping wheat on the Sussex Downs You have already met the machines they are using They are self-binders which cut and tie bundles of corn, flinging them out on the ground in their wake

A COLLECTION OF BRITISH BIRDS' EGGS

Specially painted for this work

A COLLECTION OF BRITISH SHELLS

British shells are beautiful and varied both in form and in colour. It is easy to collect them, for they are lying about everywhere on the seashore and elsewhere. The specimens depicted are: 1, Razor Shell; 2, Painted Top Shell (upper side and under side); 3, Great Scallop; 4, Variegated Scallop; 5, Ormer Shell (inside); 6, Great Whelk; 7, Ormer Shell (outside); 8, Pelican's Foot; 9, Purple Shell; 10, Wood Snail; 11, Dog Whelk; 12, Mussel; 13, Hungarian Bonnet (inside and outside); 14, Boat Shell; 15, Wentletrap or Ladder Shell; 16, Limpet.

BUILDING UP STOOKS

Mirror Features

Two or three farmhands following the self binder have the task of building up the sheaves of ripe corn into stooks Each stook consists of four or five pairs of sheaves standing on their butts with the ears of corn uppermost Usually the sheaves will remain in stook from a week to a fortnight

Fox Photos

If you have ever visited the countryside at harvest time you will know what beauty there is in a newly harvested field where the sheaves of golden-brown corn stand in stooks in neat rows It is while the sheaves are in stook that the corn dries, oats taking the longest time to dry.

whether useful or otherwise, these fruits and berries add to the loveliness of the autumn country scene. The Colour Plate in this volume will help to identify others. The farmers and country people know all about these fruits and berries: which to avoid and which to gather for use in the kitchens of their farms and cottages. It is another attraction of the countryside that there are usually more good things to eat and drink than can be found in the towns.

These are some of the things that compensate the farmer for all the work that he does. Throughout his busy year he has the never-failing satisfaction and ever-changing charm of the countryside all around him.

But there is a lot of truth in the old saying that the farmer's work is never done. Nature, like time, waits for no man, and the crops and beasts of the field demand the incessant attention of the farmer if he is successfully to gain his livelihood from them. Moreover, to a considerable extent, the fruits of his labours will depend upon forces beyond his control—the sunshine and the rain, for example. Flood or drought can spell disaster, even complete ruin for the farmer.

Those of us who are merely visitors to the country at week-ends and holiday times may envy the farmers and the country folk their lives amidst the peaceful beauty that Nature provides. But we may remember, too, that these pleasures are paid for in the hard, unceasing work that goes on through all the seasons to bring forth our food from the land.

Fox Photos.

GATHERING THE HARVEST OF WAYSIDE CROPS

In recent years a great drive has been made in Britain to produce more home-grown foods In some parts of the country the wide verges by the roadside have been ploughed and sown with wheat, oats and barley. Here is a picture of wheat being cut and gathered on the Barnet by-pass road, where excellent crops were grown.

Copyright

TRAINING YOUTH FOR MODERN INDUSTRY

Training for commerce and industry is essential, and in this photograph is seen the Drawing Office of the School of Motor Body Engineering at the Regent Street Polytechnic Here youths are trained in the methods employed for the production of private cars, passenger-carrying, public service and other types of modern vehicles

HOW THE BRAIN AND THE MIND WORK

THE human brain might be compared with the general headquarters of an army. The general headquarters receives information respecting the whole state of the army and what is happening in the various outposts. The brain is constantly receiving messages and kept informed of the state of the body, that is, of bodily movements, and changes within the body itself, as well as changes taking place outside.

Before, therefore, we consider the nature and work of the brain itself, it will be interesting to consider briefly the kinds of messages it receives.

The Brain Receives Messages

Diagram 1 illustrates these varying types of messages, or stimuli, as the scientists call them, which travel to the brain.

In the first place, there are those messages aroused by events happening in the outside world, giving us sensations of sound, sight, touch, both light and heavy, painful and non-painful, taste and smell. Secondly, there are messages informing us of the position of the body, both when it is at rest and when it is in motion. Some of these messages arise from nerve fibres in the muscles, ligaments, tendons and joints in the various parts of the body. Others are received by the brain from the internal organs of the ear.

You see, the ear is a very complicated organ which not only enables us to

hear, but also to know of the equilibrium, or balance of the body. If this part of the ear, called the internal ear, is disturbed or damaged we are sometimes unable to maintain our balance. Thus, when you turn round rapidly many times, you disturb the smooth working of the internal ear and you become "giddy."

Thirdly, there are messages telling us of the changes taking place in the internal organs of the body, including the lungs for breathing, the heart for supply of blood to the body, the digestive system which deals with the food we eat and the eliminative system which gets rid of the waste products of the body.

The Human Telephone

The messages of which we have spoken travel along chains or relays of nerve fibres and nerve cells called neurones. These might be compared with the wires of the telephone system. Now, there are two-way messages, one series of messages from the body to the brain, Diagram 2a, and the other series from the brain to the body, Diagram 2b. In the body there are many millions of these nerve processes and Diagram 2 shows you what they look like. Let us suppose that an animal sees a dangerous object and runs away.

If we compare this sequence of events with the telephone system, then the voice of the caller, the sensory message, which for our animal is the sight of the dangerous object, travels along wires, the sensory nerves, to the exchange, the brain, where it is accepted and interpreted. Then the message is sent from the brain, along a series of wires, the motor nerves, to the receiver of the message, the muscles, which then carry out the appropriate movements of flight.

Just as in the telephone system we have the central exchange including local exchanges which can contact any area, and trunk exchanges which can contact any area over which the telephone wires run, so in the nervous system we have the central nervous system, consisting of the spinal cord and the brain, as well as the nerve processes lying outside the central nervous system. Most of our messages travel to the brain by way of the spinal cord. However, the nerves of the face are connected directly with the brain through small holes in the skull. These nerves carry messages relating to sensations of smell, taste, sight, and hearing and movements of the face and eyes. Moreover, there are certain messages which use only the local exchange, or the spinal cord.

Thus, when you unknowingly touch a hot plate, you immediately, and automatically remove your hand. Such a non-willed automatic action is called a reflex action. We have spoken of a reflex action of the spinal cord, but parts of the brain are also responsible for such automatic bodily actions. The tasks which the lower parts of the brain perform are carried out without our consciously willing that they be performed. We will now consider the work of the brain, taking each part in turn.

THE HUMAN BRAIN

The Grey Matter

When we look at a brain, we see a mass of grey and white coloured matter. The grey matter consists of millions of tiny nerve cells, each of which has a fine nerve fibre. It is these fibres which give the brain its white appearance, and they serve either to link up various cells within the brain, or by passing to other parts of the body, to connect the brain with the rest of the body.

Parts of the Brain

The brain is a continuation of the spinal cord, and perhaps it will help us to understand the brain if we make a very rough comparison. Imagine a Scout's pole, the top of which is

TRAINING HAND AND EYE

Copyright

In this picture we have a view of the School of Motor Body Building, where students are at work in the metal shop, shaping aluminium panels for car bodies. Finished work is hanging from the balcony and in the background are "wheeling machines," used to smooth off and polish the panels. Oxy-acetylene welding, painting, trimming, coach joinery and body assembly are also taught.

Copyright

The young men seen in this picture intend to become tailors and to be first class in their work. They are students at the Tailoring School of the Regent Street Polytechnic and are taking a lesson in fashion drawing, the object being to improve the eye for line, colour and style.

divided into three by notches. An orange, cut in half, is placed between the top division of our pole, and another smaller orange, also cut in half, is placed against the third division as shown in diagram 3. In the diagram, the main parts of the brain have been indicated and named.

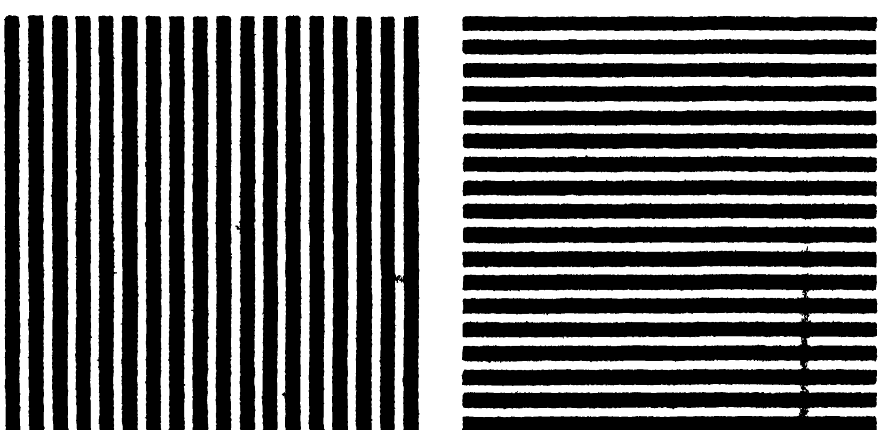
However, this is a very crude comparison, and we must now consider the various parts of the brain as they really are. Diagrams 4 and 5 are drawings of the brain as it actually appears. Diagram 4 shows how the human brain is situated inside the human skull, and Diagram 5 shows the parts in greater detail. In diagram 5, the mid-brain and inter-brain are situated in between the two parts of the cerebrum and are not, therefore, seen in the diagram.

Brain Stem and Mid-Brain

The brain stem contains the pathway by means of which the spinal cord is joined to the rest of the brain, and along this pathway impulses or messages travel from the spinal cord to other parts of the brain, and from the brain to appropriate parts of the body. It contains nerve fibres which control our breathing, others which regulate the heart-beat, and therefore the control of blood throughout the body, and still other centres which control processes necessary to eating, swallowing, the secretion of saliva, as when our mouths water at the sight and smell of an appetising meal. The brain stem also controls the work of the digestive system during the assimilation of food

Now, when you consciously move your eyes, your head automatically moves in the same direction. Similarly, if you consciously move your head, the eyes automatically move in the same direction. In short, they work together; you *will* the movement of the one, the movement of the other is automatic or reflex in character. Again, if you hear a noise, you tend to move the head in that direction, while some animals also prick their ears in response to sound.

These simultaneous movements of the eyes, ears, and head are protective

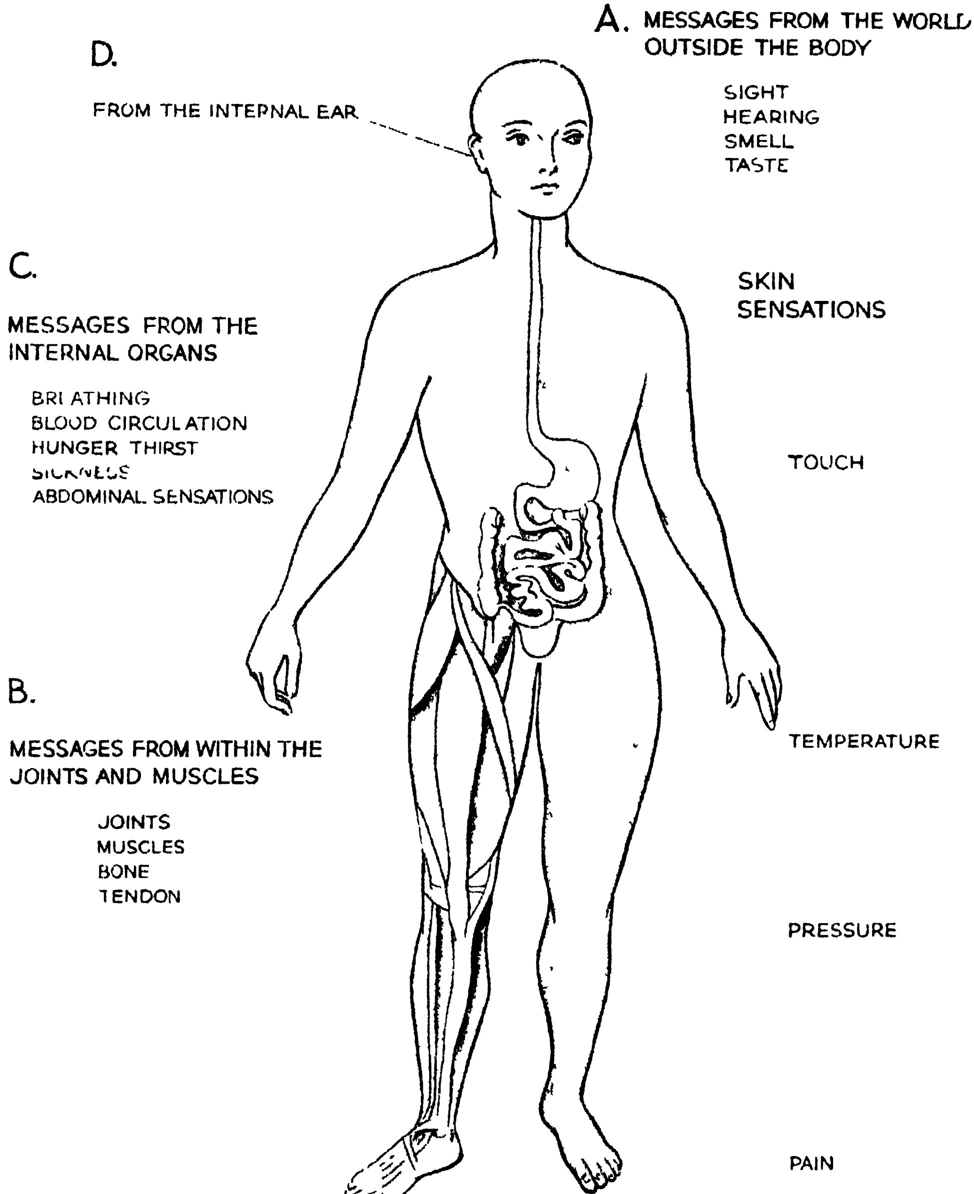


Specially drawn for this work

AN OPTICAL ILLUSION

Here are two squares of the same size If you prepare similar squares for yourself and hold them a little apart, the one with the horizontal lines will seem higher than that with the vertical lines

MESSAGES TO THE BRAIN



Specially drawn for this work

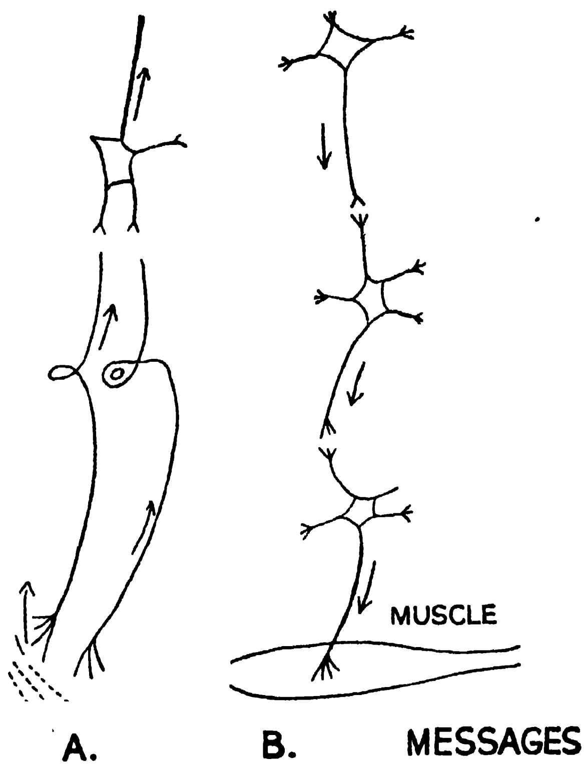
Diagram 1 Here we can see the kind of messages received by the brain, and the sensations of which we are made aware There are messages informing the brain of what is going on in the world outside the body (A), and other messages which tell the brain of what is happening inside the body (B, C, and D).

devices which are especially useful to animals, enabling them to be able easily to inspect the events in the outside world so that they may then assess their danger value. The mid-brain contains the cells and fibres which enable the automatic or reflex actions of the eyes to follow a willed movement of the head, and the automatic or reflex action of the head to follow a willed movement of the eyes.

Concerning the Cerebellum

The cerebellum, or lower outgrowth of the brain, is sometimes called the hind-brain because it is situated just above the back of the neck, as you can see from Diagram 4. It is round in shape, but is divided into two hemispheres, which are connected by means of nerve fibres, while other nerve fibres connect the cerebellum with the rest of the brain and also with the joints and muscles of distant parts of the body. The outside of the cerebellum consists of a layer of grey matter which has deep folds, as, for example, has a handkerchief when it is lightly screwed up in the hand.

These folds have a special purpose in that they enable a large amount of grey matter to be tucked away within a very small space. The section of the brain called the pons, as marked in diagram 5, consists of nerve fibres which connect the two hemispheres. The name "pons," meaning "the bridge," is most appropriate because this part of the brain is a kind of bridge which connects the brain stem with the upper parts of the brain as well as connecting the two hemispheres of the cerebellum. In appearance, you might compare the pons and the cerebellum to a signet ring on a finger, the pons being the ring and the cerebellum a very large signet.



MESSAGES ALONG THE NEURONS

Diagram 2 In A we see the beginning of the journey, which a touch on the skin takes along the sensory neurons on its way to the spinal cord and the brain In B is seen the final pathway of the message from the brain (or spinal cord) along the motor neurons to the muscle

The Work of the Cerebellum

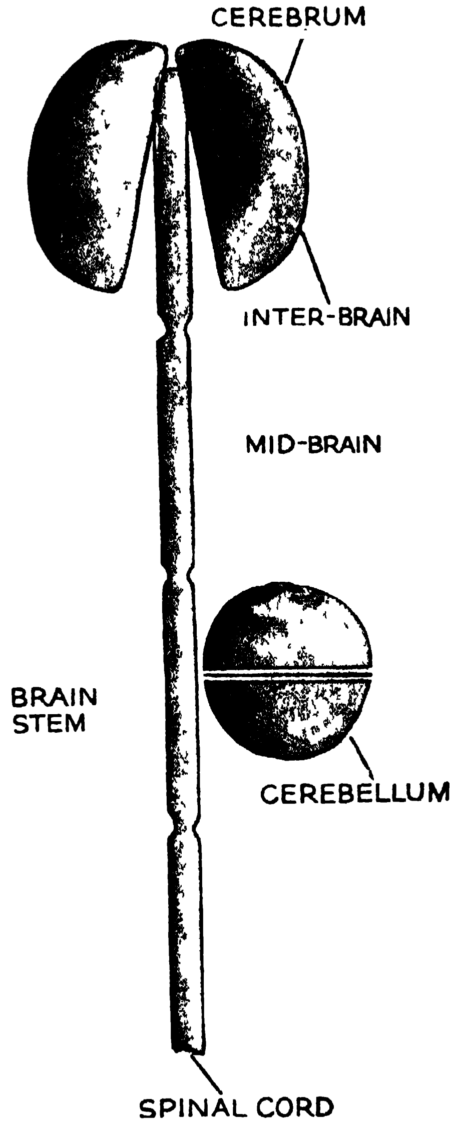
The chief work of the cerebellum is to co-ordinate the various movements of the body, so that the muscles work harmoniously together. For the tiny child, when he begins to learn, walking is a very difficult process. His movements tend to be jerky, one leg completing its movement before the other leg begins. The movements are carried out consciously, the higher parts of the brain taking part in these early attempts Soon, however, the process of walking becomes a smooth, harmonious activity, carried out without conscious thought. By this time, the cerebellum has taken over this task, leaving the higher centres of the brain free for other work.

It has been discovered that an animal deprived of its cerebellum does not suffer from paralysis, or inability to move the muscles of the body, but its movements are shaky, jerky, and poorly controlled. In man, disease or injury to the cerebellum causes the same lack of muscular control, and he is unable to carry out the movement of his muscles smoothly and accurately. If, for example, he is asked to touch his nose with his finger, his arm moves jerkily and he fails to hit the mark.

The Inter-Brain

The inter-brain, as we shall call it, is a mass of grey matter lying just above the mid-brain and at the base of the cerebellum. It is the part of the brain which enables us to sense extreme sensations, extreme pain, extreme heat and extreme cold. There are nerve centres which enable the body to adapt itself to these extreme changes. Thus, for example, on a boiling hot day these centres enable the body to lose heat by controlling chemical changes in the body and by increasing the activity of the sweat glands. Further, these centres are concerned with violent reactions - emotions of hate, rage and fear. These violent reactions are usually controlled by the higher centres of the brain.

If, however, these higher centres are removed in an animal, there results a condition of uncontrolled emotional outbursts, such as anger, shown by snarling, clawing and lashing of the tail. Extreme fear is also seen. The heart beats fast, the blood travels at a very quick rate through the body, the pupils of the eyes enlarge and the hair on the body rises in much the same way as in a cat when it is chased by a dog. In man, alcohol tends to inhibit or prevent control being exercised by the higher centres of the brain. It sometimes happens that a man who is intoxicated displays extreme emotions such as we have described in the animal deprived of the cerebrum

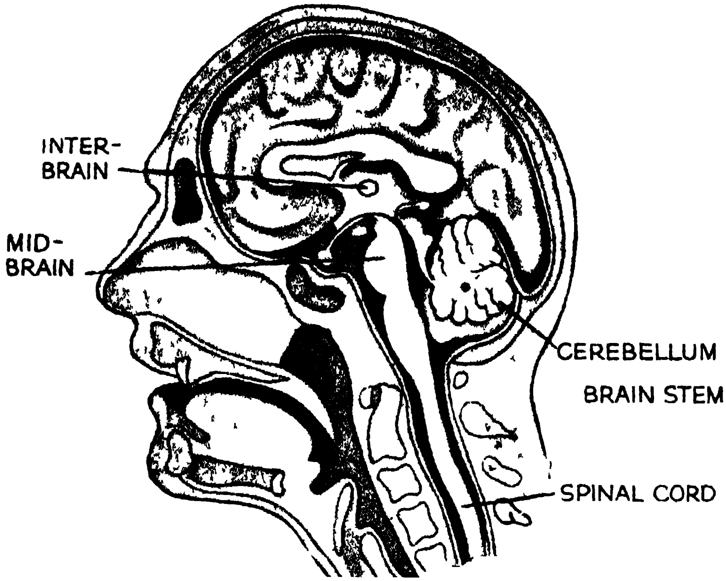


A SIMPLE COMPARISON

Diagram 3. In this drawing the brain is compared with a notched scout's pole, showing the inter-brain, the mid-brain, the brain stem and the spinal cord The two cut oranges represent the two halves of the cerebrum and the cerebellum.

The Cerebrum and Its Work

The cerebrum is the largest and most important part of the brain in man. In lower creatures, the cerebrum is smaller in proportion to the rest of the brain. Diagram 6 shows how when we ascend the evolutionary scale from the fish to



PROTECTOR OF THE BRAIN

Diagram 4 The skull acts as a protector of the brain Between the brain and the skull are three layers of fine, supple skin which protect the brain from the hardness of the inside surface of the skull

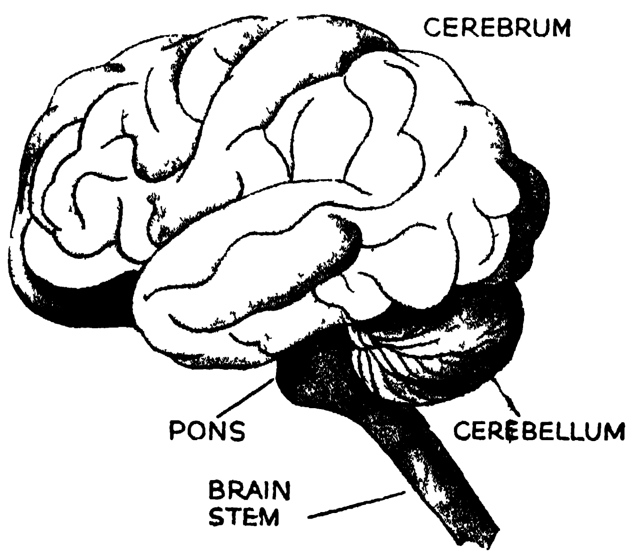
extracted from the shell. The cerebrum in human beings, however, is larger in bulk than the cerebellum, and fills most of the skull

Moreover, the work it has to do is more varied An interesting difference between the cerebellum and the cerebrum is that in the cerebellum, the right hemisphere controls the joints and muscles on the right side of the body, and the left hemisphere looks after the joints and the muscles on the left side of the body

In the cerebrum, however, this is not so, for here the left hemisphere controls and looks after the opposite or right side of the body, and the right hemisphere controls the left

man, the cerebrum (marked C) becomes proportionately greater, until in the dog and monkey it is larger than all the other parts of the brain put together. In man it is so large that all the rest of the brain seems very insignificant.

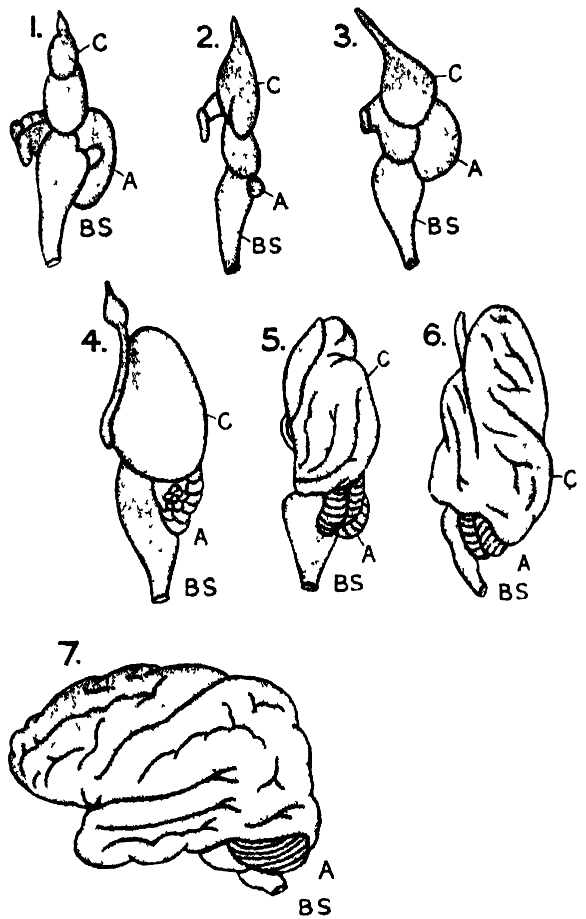
In so far as it consists of a deeply folded, outer grey crust of nerve cells, and an inner layer of nerve fibres; in so far also as it has two hemispheres joined by nerve fibres, and has nerve fibres connecting it with the rest of the brain and with distant parts of the body, the cerebrum is not unlike the cerebellum in general structure. Diagram 7 shows the right half of the cerebrum. In the diagram, you can see the deep folds of which we have spoken. In appearance, the cerebrum is not unlike the kernel of a walnut which has been



A SIDE VIEW OF THE BRAIN

Diagram 5 Here we see parts of the brain as they are seen on the left side The mid-brain and the inter-brain are hidden from view

side. You see, the fibres leaving the cerebrum cross each other before they reach the spinal cord. Diagram 8 shows the pathway of nerve fibres from the cerebellum and cerebrum. You can see how the fibres from the cerebellum cross over to the other side of the body when they reach the brain stem.



BRAINS OF DIFFERENT ANIMALS

Diagram 6 Here we see the brains of (1) Salmon, (2) Frog. (3) Pigeon. (4) Rabbit. (5) Dog. (6) Monkey. (7) Man A is the cerebellum, BS mid-brain, C the cerebrum, which gets relatively larger as we ascend to man.

The Cerebral Cortex

The cerebral cortex is the name given to the grey matter, or nerve cells, which cover the cerebellum. The cerebral cortex is the seat of conscious reactions. It contains centres by means of which we are made consciously aware of our surroundings; it is the organ of volition or will, for when we will to move some muscle or to perform some task, the nerve cells in the cortex are first stimulated, and messages sent to various parts of the body.

The cortex is also the centre for higher thought processes, reasoning, memory and speech. In short, this area of the brain firstly makes us conscious of bodily sensations, secondly enables us to use our will or volition, and thirdly, enables us to carry out thought processes.

The Map of the Cortex

Now, it has been found, as a result of experiments on animals, and from the observation of the effect of brain diseases and injuries to the brain in man, that certain specific areas of the cortex perform, and are responsible for, certain specific tasks. Scientists have, as a result of their observations and experiments, been able to map out these various areas of the cortex, and diagram 9 is a sketch of the left half of the cerebral cortex mapped out according to the tasks which the various parts perform. From a study of the diagram you can see that there is :—

1. A motor (or muscle movement) area from which summonses to action are dispatched to the muscles of the body. Each part of the body has its special small area within the motor cortex. When this part of the motor area of the right hemisphere is stimulated by a weak electric current in an animal under anaesthetic, it causes movement of the appropriate muscles on the left side of the body. Disease of, or removal of, the motor area in any one hemisphere produces paralysis of the opposite

side of the body. If the motor areas of both the hemispheres are injured, the whole body becomes paralysed.

2. A sensory area which makes us conscious of sensations coming from the muscles and skin. Patients who have had to undergo brain operations using local anaesthetics only, have sometimes permitted the surgeon to stimulate these sensory areas. The patients reported definite sensations of numbness or tingling which they localised in specific parts of the body

3. An auditory area, which is a special area for hearing, and

4. Another special area for visual perception, the visual area. In animals it is difficult to say when a sensation appears, but when the auditory area of an animal is stimulated there is a short delay, then a pricking up of the ears; the stimulation of the visual area is followed by a turning of the head presumably in the direction from which the visual impulse is thought to come.

The rest of the cerebral cortex is sometimes called the "Silent Area" as these parts do not carry out special functions, as do the specific areas considered above. They are also known as "Association areas." To associate means to link one, two or more ideas together. These areas are said to be concerned with learning and memory, thought and reasoning processes; in short, the mental processes which characterise man, and in the exercise of which, he is distinguished from the animal.

HOW THE HUMAN MIND WORKS

So far we have been considering the brain, the scientific study of which is carried out by the physiologist. Now, we need to consider man's mind, the student of which is a psychologist The work of the psychologist, like that of any other scientist, is to observe, to classify the facts which he observes, and then to make scientific laws concerning his observations.

A scientific law says, in effect, "Do so-and-so, and such-and-such will follow," or "If so-and-so happens, such-and-such will follow." Thus is man able to predict or foretell what will happen. It is this power of prediction which gives man control over the world in which he lives.

The psychologist is concerned with mental events or what happens in the mind. He is concerned, that is, with such facts as sensations, perceptions, emotions, feelings, memory, intelligence and character. Now, for Western man, this study of mental processes is comparatively new. Western man has, especially during the last four hundred years, expended most of his energies in examining objects and events in the world outside him. Thus, he has learned much about the laws which govern their movement and behaviour, and has built up a highly technical civilisation. But the study of the mind has been neglected, and often such a study is regarded by us as strange, if not a little mysterious, and one in which we do not feel quite as much

THE FOLDS OF THE BRAIN

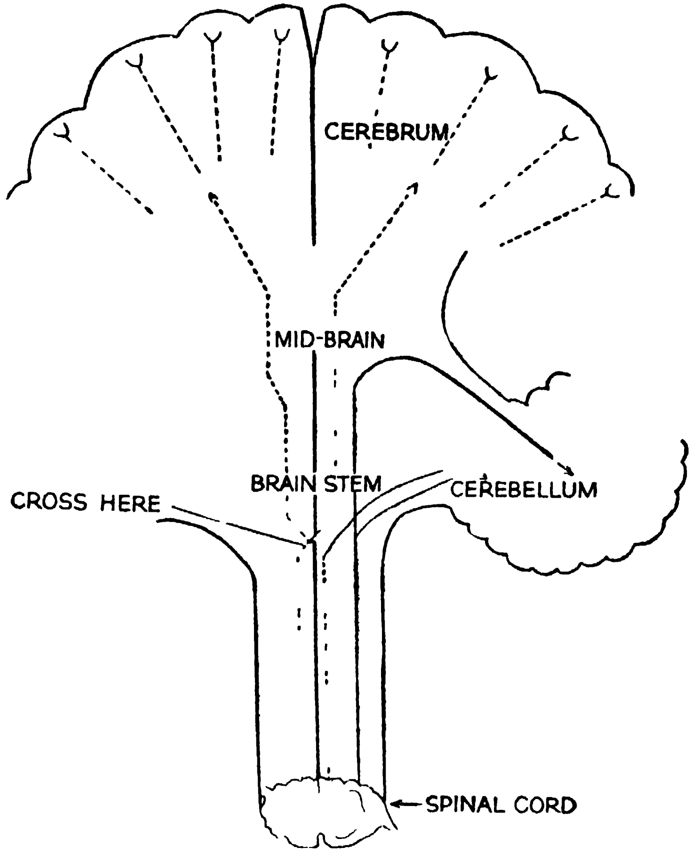
Diagram 7 Right side of brain, showing the deep folds which enable a large amount of grey matter to be tucked away in a very small space

at home as we do when we consider objects in the outside world

What is Mind ?

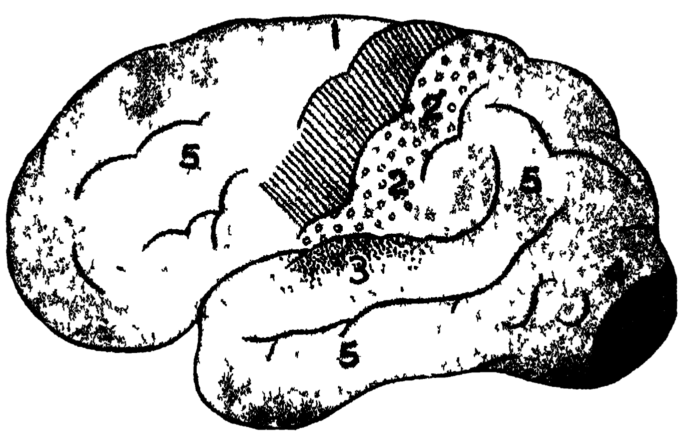
Here we ask a question which philosophers have pondered throughout the ages

Some consider the mind as something which is caused by and is the result of movements and changes in the body, more especially in the brain, as Hobbes, a seventeenth century philosopher, put it, "The brain secretes thought as the liver secretes bile" However, such an explanation is hardly satisfactory because, as we shall see later, the mind is both active and creative, and it is certainly difficult to explain this creativity and activity in terms of bodily movements and changes To take an example, we eat a big supper, and we dream Now, it may be true that the eating of the big supper causes the digestive system to work overtime and this may stimulate the cells of the brain and so give occasion for dreams But, in dreaming,



FROM RIGHT TO LEFT

Diagram 8 This shows the nerve fibres from the cerebellum and cerebrum to the spinal cord fibres Notice how fibres from the cerebrum cross to the other side of the spinal cord In the cerebrum the left hemisphere looks after the right side and the right after the left side of the body



A MAP OF THE BRAIN

Diagram 9 This left view shows the special areas of the brain 1 The motor area responsible for movements of the muscles 2 The sensory area where sensations of touch etc, are perceived 3 The auditory or hearing area 4 The visual area responsible for understanding things seen by the eyes 5 Association areas responsible for learning memory and thought processes

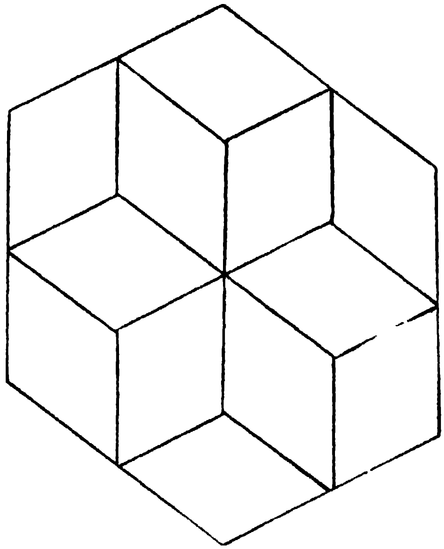


Diagram 10 (*a*)

we create scenes and events. Some may be more or less repetitions of what we have experienced during our waking hours, others may be new and strange. We might even write a story, book or poem. Coleridge, the poet, created his poem "Kubla Khan" during sleep, and wrote it immediately on waking.

Thus, there is something creative and active, which is influenced by the brain and body but is nevertheless something other than either. The body, as a body, obeys the laws of chemistry and physics, the laws which are obeyed by objects in the outside world. If, for example, a human body falls from a height, it will obey the same laws as did the lead balls which Galileo dropped from the leaning tower of Pisa. A human body can be weighed and measured, but we can hardly measure the inspiration which enabled Beethoven to write his musical works. A brain and body, but not a thought, may be crushed with a hammer.

Relation between Body and Mind

If the mind and body are so different, how can they influence one another? We accept the fact that one object can be the cause of movement or change of behaviour in another. They are both material objects, consisting of what the scientist calls "matter." But how can a thought cause changes in the body? Yet, experience tells us that the mind does affect the body.

We decide to do something, that is, we make an act of will, which is a mental event, and the body obeys. Worry and anxiety, mental events again, have been found to cause bodily ills such as indigestion and stomach troubles, heart diseases and asthma, and in certain cases, cures have been obtained by treating patients psychologically when the use of drugs has failed. Further, experience tells us, that the state of our bodies can affect the state of our minds. We have indigestion and we feel gloomy and depressed. We take drugs and we have visions of ecstasy, or we lose our will power or become obstinate.

Philosophers have given many theories to account for these body-to-mind and mind-to-body influences, but it is perhaps true to say that our commonsense view is as satisfactory as any of the other theories of philosophers. The commonsense view is that the body and mind are two separate elements of man, and they obey separate laws. Nevertheless, one can affect the other. How they do this, we do not know, but by observing human behaviour, we must accept the fact that they do so influence each other.

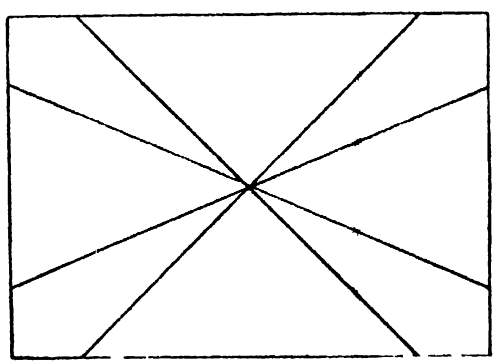


Diagram 10 (*b*).

Mental Behaviour is Purposive

The main feature of mental behaviour is that it is purposive. Objects obey

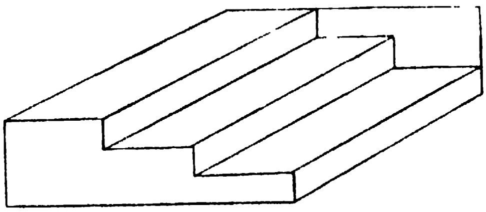


Diagram 10 (*c*).

mechanical laws and are moved to action by the force of other objects, or else are still. In mental activity, however, there is a goal or purpose and the mind works forward to accomplish its purpose, not blindly, but actively exploring all the time and changing its behaviour according to changing circumstances. Now, a rubber ball running downhill is impelled forward by the force of gravity. If, in its forward movement, it hits an obstacle, say a wall, there its " activity " ends.

Compare the boy who wishes to obtain some apples on the trees on the other side of the wall. He runs down the hill ; the force of gravity helps him along, but he is also urged by his desires. When he finds the wall too high to climb, he does not stop in his activities but will explore other means of obtaining his goal ; nor will he stop, until either the circumstances are greater than he can overcome, or he reaches his goal.

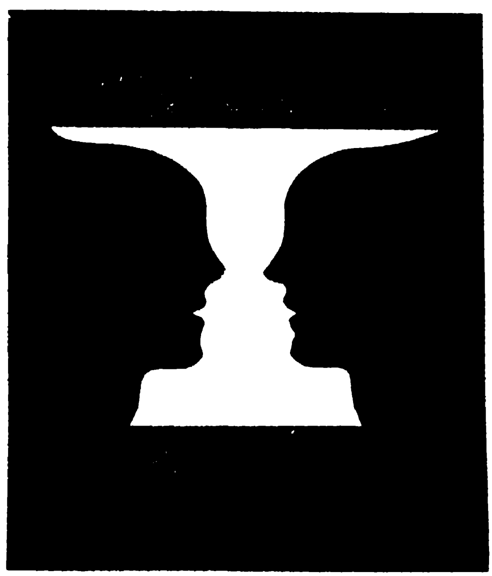
The Mind is Active

The example of the boy and the apples shows us that the mind is constantly active, solving problems and so adapting bodily movements to changing circumstances. Even in the simple process of perceiving, our minds are active. A simple example of this is provided by Diagrams 10 (a, b, c and d). If you look separately at each diagram concentrating your attention all the time, you will see that each drawing can be seen in different ways, but not in more than one way at the same time. Try this little test with each diagram and you will experience these changes from one drawing to the other.

An interesting illustration of the mind's activity in perceiving is given when we look at those puzzle pictures which you find in children's books. For example, there is a forest scene and you are asked to find among the trees, the woodman, his wife and three children. At first you cannot see them, but by searching you find them.

Perceiving is a Form of Thinking

When you discover the woodman and his family, they stand out so obviously that you wonder how it was that you did not see them immediately. But in order to experience this, your mind had to be active. Then we make a judgment, to ourselves, if not in words to someone else, and we say, " There is the woodman." Perceiving is thus a form of thinking and is followed by a judgment of what to us is fact. But there are other processes of



SEEN IN DIFFERENT WAYS

Diagrams 10 (*a*), (*b*), (*c*), (*d*). The mind is very active in perceiving. If you look carefully at each of the drawings on this and the opposite page, you will discover that each can be seen in two different ways.

thinking which must be distinguished from simple perception as we have so far considered it.

Discovering Relations

When two objects or ideas are given, we also discover that there is some relationship existing between them. When we say that we "see" that two objects are "similar," we do not see "similar" as we see "red" when we say "The pillar box is 'red'." The seeing of "red" is what the psychologist calls a "percept." The "seeing" of "similar" is a concept, that is, it is conceived by or produced by the mind. This mental process of discovering of relations is a very important ability of the mind, for it enables us to see how events and objects in the outside world are connected one with the other. Thus we speak of one event as being "the cause of," or "the result of," just as we speak of one thing being "more beautiful than" or "bigger than" another.

Discovering New Ideas

Suppose you were given the idea "black" and the relation "opposite." From these two you obtain the third and fresh idea "white." You obtain another idea from two ideas given.

Again, suppose you were given two terms *e.g.*, "coal" and "locomotive." You see there is a relationship between them, for coal enables the locomotive to run. Suppose you were given yet a third term "motor car." You can then find a term, namely "petrol," which stands to motor as coal stands to locomotive, that is, the fuel from which it obtains its energy to move.

We have shown here how the mind is active, first in seeing objects and the qualities they have; secondly, discovering relations between objects, and, thirdly, finding new ideas or objects. These are very simple examples, but the minds of great scientists work in this way to discover new relations between objects and new facts and laws which have not been discovered before.

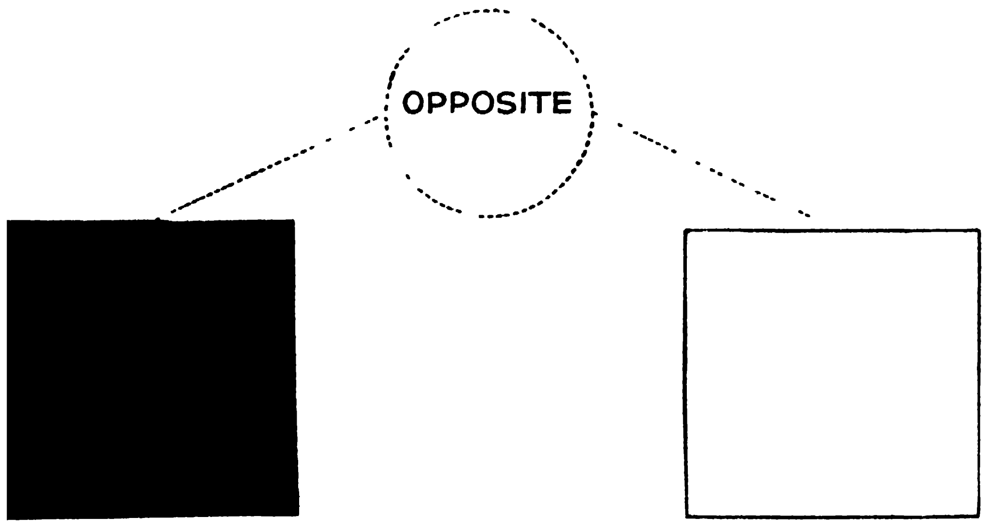
Intelligence

Intelligence is the power to perform the types of mental activities we have described. Psychologists have made out special tests to find out how well you can perform these mental tasks. The relationships and new items can be made more and more difficult, and the more difficult the relations you can see, and the more difficult the new terms your mind can discover, the greater your intelligence score.

You must not confuse intelligence with knowledge. A man may gain a lot of knowledge, not only by reading and schooling, but also by travel and life experience. This increases the number of ideas he has in his mind, but not the power of seeing difficult relations and conceiving new ideas. We might compare intelligence with the maximum speed which a car can go, and compare the amount of knowledge a man has obtained, with the number of miles the car has travelled. Now, a car may have travelled 40,000 miles when its maximum speed is only 50 miles an hour. On the other hand, a car may have travelled only 10,000 miles, but have a maximum speed of 95 miles per hour. In the same way, a man with a smaller intelligence, may have greater knowledge than a man with a higher intelligence.

Aptitude

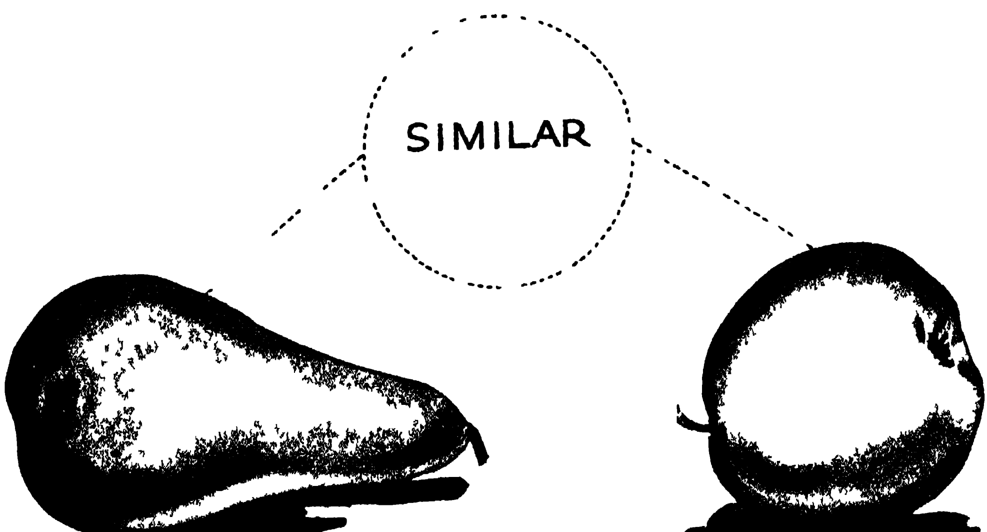
Psychologists call intelligence "general mental ability." In order to become a brilliant mathematician, philosopher and scientist, a great amount of "general mental ability" is needed. However, besides this general ability, we have also special abilities, for example, in music, drawing, painting, craftwork, and motor mechanics. To be good at these we need not necessarily have a high intelligence, or "general" ability, but we do need a "special" ability or special aptitude in the



particular subject. Certain tests which psychologists have devised are attempts to predict what tasks you are best able to do. They are called Aptitude Tests.

Learning

There are two main ways of learning. We may learn without realising that we are learning. This we can call "unconscious" learning. A child learns more in the first five years of life than in any other five years of his life though he may not go to school. Besides learning to walk and talk, he learns skill in handling objects, to know what they are used for. He learns also the kind of behaviour his parents



RELATIONSHIP BETWEEN DIFFERENT OBJECTS

Diagrams 11 (*a*) *and* 11 (*b*) On this page we have two drawings. In one we see a square which is black and one which is white and the mind conceives the relationship 'opposite'. In the same way we perceive that the apple and pear are both fruit and we say they are 'similar' but we do not *see* 'similar' as we *see* the apple and pear.

expect from him. He learns to like some things, dislike others; he learns to like certain people and to hate and fear others.

In school, much learning is conscious learning. We "pay attention" to the teacher, and he explains facts to us.

In learning, we use our "memory." How we are able to "store up" so many memories, or what exactly "memory" is, is ultimately a mystery. All we can say is that we are able to remember, and that our minds can remember more easily, provided that we understand what we are learning, that is provided we see the relationships between the various items of what we are learning. We can learn merely by rote, or "by heart" (as we put it), without understanding. But this is a very poor way of learning, not only because it is more difficult, but also because things we learn merely "by heart" are easily forgotten. It is always a good rule, therefore, in all your learning to understand, and not merely learn "parrot fashion."

Secondly, learning depends on our feelings about the subject we are learning. Interest and desire to learn are the lubricating oil of the mind. They enable the mind to learn more easily and more quickly. That is why the good teacher is the one who arouses our interests and desires to learn by using pictures, diagrams and stories as aids to learning.

Mental Energy

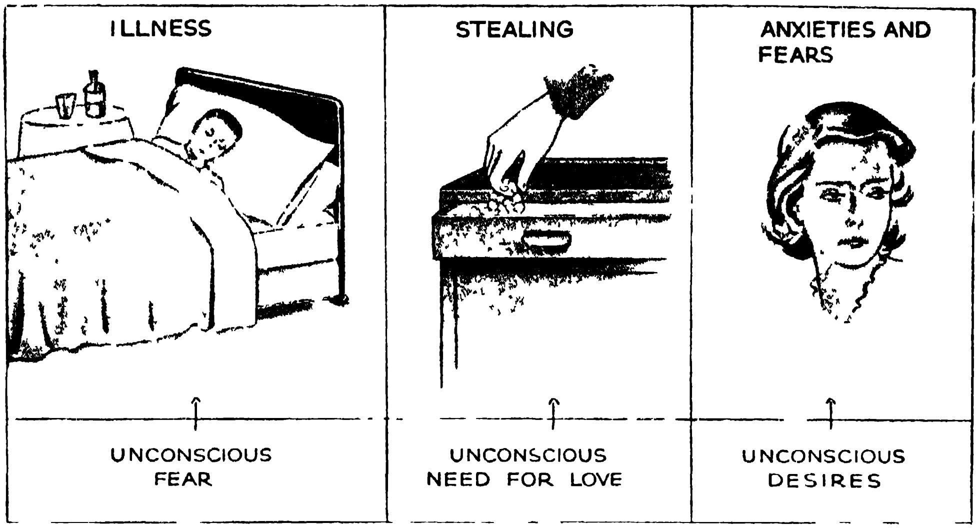
If we compare the mind with a motor-car engine, we may say that so far we have described the engine of the mind, how the rods and pistons link in one with the other and what work each does. But what is the source of energy of the mind? What corresponds in the mind to the petrol of the car? Here again, we are faced with an ultimate mystery. Some thinkers speak of "mental energy" which they call by various names including "libido," "élan vital" or "the will to live" by which they mean a general source of energy unseen in itself, but which they conclude must exist from their observations of human behaviour

Rather than speak of "mental energy" perhaps it is better to speak of "needs" or "instincts." Man has many needs, and in order to satisfy these needs, he is prepared to work the "engine" of his mind.

These needs are, therefore, the petrol which the mind uses. Some of these needs are needs which his body demands These needs might be called appetites and include the need for food, drink, and physical exercise. Much of our mental energy is carried on in order to satisfy these bodily needs. In most animals these needs are the only needs. If you want an animal to learn, or if you wish to train an animal, the best way is to refuse him food till he is hungry, and then offer him food as a reward for carrying out the task you wish him to do.

Human beings acquire other needs, and these needs vary in strength from one person to another. We need to assert ourselves, and we gain much satisfaction from mastering a task.

We like also to please other people and win their affection and esteem so that they will say "What a good boy you are." We may also wish that other people will admire us, and we are urged to activity by this need to impress them so that they recognise how clever we are. Furthermore, we need to join with our fellows and to be able to do the many tasks they do. We would feel "out of it" if others in our little groups could do things which we could not do. It is pleasant to share the work, play and interests of others and to do so we must use our mental energy to learn the skills, the rules of the games which others play. When we are older, our needs may become less self-centred. We have a wife and children and we are urged on by



THE UNCONSCIOUS MIND

Diagram 1 In this picture are shown three examples of how mental factors, of which we may not be fully aware, may cause us to act in strange ways.

the need to provide for them. Finally, we might feel that our efforts will benefit not only ourselves and our families, but the whole of the human race, and this acts to further our mental efforts.

So, you see, when we are mentally and physically active, we are moved to action by motives or needs. Not all man's needs have been given here. Man has many needs which urge him to mental activity and these needs are sometimes called instincts. To understand why a person attempts to solve particular problems, it is necessary to explain not only how he thinks, but also why he thinks, that is, what real needs does he hope to satisfy by his activity.

The Unconscious Mind

So far we have spoken as if man is aware of all his mental processes. This however, is not generally so. Often we are not fully aware of our desires and needs. We often have feelings of anxiety though we know not why. It is because of these things that psychologists say we have an unconscious mind.

A boy has to take an examination. He has fears about it, but is not aware of them because he refuses to admit them. He "represses" his fears, as the psychologist puts it. So there arises a conflict in his mind. One part says, "I will take the exam," the other says "You are afraid." Then he becomes ill, and so he does not take the exam., nor does he recognise his fears. In short, his unconscious mind discovered a way out of his fears.

In much the same way, a soldier who is about to perform some dangerous manoeuvre against the enemy, may "repress" his fears, and develop paralysis of the arm.

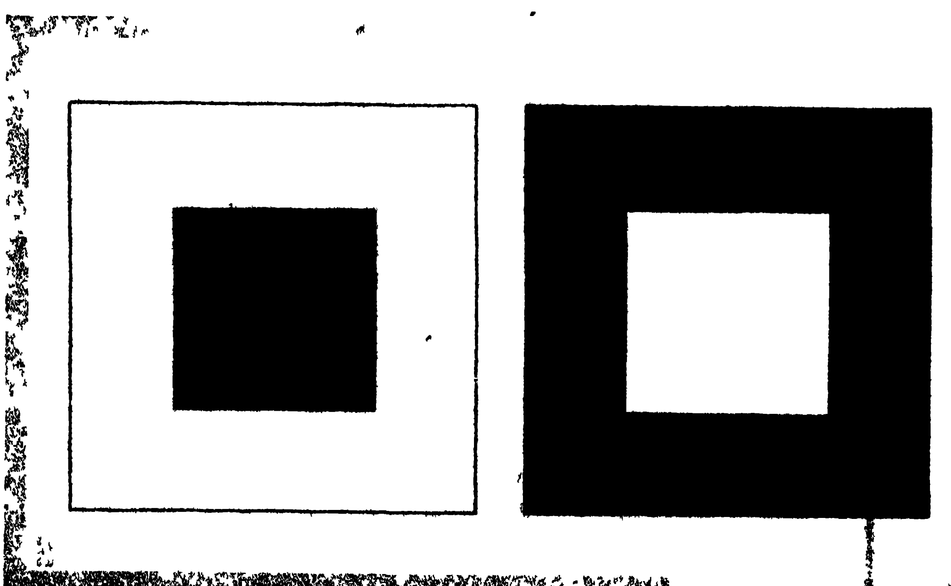
In both these cases, the fears which they felt were natural, and most people would have similar fears in like situations. But their pride was so great that they were not prepared to admit fear, even to themselves, and because of this, they could not control their fears. The work of the psychologist would be to get them to admit their fears, and to see that such fears are natural to all men. Then they would understand why they had become ill. Having accepted their

fears, they would not be overwhelmed by something of which they are unaware If the treatment is successful, both the illness and paralysis would disappear, and they would be prepared to carry out the tasks.

Again, a person may "repress" a need for love and say, "I am tough, too tough to want sloppy love." Here there is a conflict in the mind between a vain need "to be tough" and a pathetic need for love and affection. Then suddenly, he begins to steal, and cannot stop himself, or tell why he must steal.

People often "repress" feelings and desires they think they ought not to have. As they repress them and are unaware of them, they experience fears and anxieties, and they cannot account for them. Their fears and anxieties arise because they are afraid these unconscious hatreds and desires will be unloosed. If, however, they can be shown these unconscious factors, they will then be able to control them, and do something about them. Thus, they may "work off" their hatred by "attacking" a mountain and making a tunnel through it, or becoming mountaineers and "overcoming" the mountain. Similarly, other energies may be deflected into socially useful channels by the care of, and service to, others. This the psychologist calls "sublimation," which means the turning of energy, which might but satisfy only an individual need, to work which is socially acceptable and maybe socially useful

Dreams are expressions of our unconscious desires and our unconscious fears. The psychologist is, therefore, very interested to know of, and to interpret the meaning of his patients' dreams. We generally feel that our dreams are rather silly and muddled and best forgotten In the Old Testament, dreams are given quite a great deal of prominence To the psychologist also, they are important and interesting, for they help him to understand the activity of the unconscious mind



ANOTHER OPTICAL ILLUSION

Look carefully at the two squares in this picture The white square has a black centre and the black square has a white centre The white central square seems larger than the black central square, although actually they are exactly the same size